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A CLIMATOLOGY OF A NEWLY-DEFINED TROPOPAUSE USING SIMULTANEOUS OZONE-TEMPERATURE PROFILES

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A physical distinction between stratosphere and troposphere can be made in terms of potential vorticity or ozone. The World Meteorological Organization (WMO) tropopause, based only on thermal stability, does not always separate the different physical properties of the two regions. It is the purpose of this paper to show that the altitude in a vertical ozone profile at which ozone, and therefore potential vorticity, begins to increase rapidly is determinable from the temperature profile alone. The tropopause definition devel-

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oped here reduces the WMO temperature gradient and thickness criteria and relies on the relative change of temperature lapse rate. The new definition determines heights of the tropopause that are in excellent agreement with ozone profile information.

The proposed tropopause definition was applied to an archived ten-year global radiosonde data set to prepare a climatology. The definition was also applied to an archived set of several thousand ozonesonde temperature profiles to prepare a climatology of vertical ozone gradient at the tropopause.

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I. RESEARCH OBJECTIVES

The objective of the research effort is to re-evaluate the conventional definition of tropopause from the viewpoint of stratospheric-tropospheric exchange using simultaneous ozone-temperature profiles. A new objective definition of tropopause that is consistent with ozone evidence is to be formulated and applied to a ten-year global set of standard radiosonde temperature profiles to prepare a climatology. The new tropopause climatology will be used to estimate the seasonal change of stratospheric mass resulting from seasonal adjustments of the tropopause height and to examine the year-to-year change of total stratospheric mass in relation to the tropical QBO, stratospheric sudden warmings, and the solar cycle. The new tropopause definition will also be applied to a large set of ozonesondes that have simultaneous ozone-temperature profiles to prepare a climatology of vertical ozone gradients at the tropopause and to subsequently estimate diffusion at the tropopause from these gradients.

II. RESULTS

A. Introduction

The troposphere is characterized by an average decrease in temperature with height. In it are contained all of the phenomena meteorologists refer to as weather, and, on the large scale, it is considered to be well mixed. On the other hand, the stratosphere is characterized by a constant or increasing temperature with height. It is considered to be a highly stratified region of the atmosphere dominated by horizontal flow and little vertical mixing. The tropopause is defined as the boundary separating the troposphere and the stratosphere. Ideally, this boundary is represented by an abrupt change in thermal stability. In reality, factors such as latitude, longitude, season and synoptic weather situation can make the determination of the tropopause height difficult and arbitrary.

Because of the differences in the average temperature structure between the troposphere and the stratosphere, the tropopause is most often defined in terms of an abrupt change in the temperature lapse rate. The World Meteorological Organization (WMO) has adopted a rigid definition of tropopause based upon thermal stability (WMO, 1954). This tropopause, often referred to as the "conventional" tropopause, is used by meteorological organizations and researchers throughout the world. Occasionally, variations from the WMO tropopause definition can be found in the literature. For example, Thompson and Wolski (1977) modified the definition for application to satellite-retrieved temperature profiles. Kochanski (1955) altered the definition so it would apply to mean profiles, while Staley (1962) applied the WMO definition to mandatory-level sounding data rather than significant-level sounding data. The WMO tropopause definition may yield multiple tropopauses in a single temperature profile, and Angell and Korshover (1974) found that the tropopause with the minimum temperature was best suited for their study of long-term fluctuations of tropopause pressure. The common point among all of these methods is that the tropopause is based on thermal criteria. Danielsen (1959) presented an historical review of tropopause concepts and gave insight into the difficulties of defining a tropopause by arbitrary thermal criteria. One of the main difficulties is the tendency for the conventional tropopause to jump from the base of one stable layer to the base of another.

Another approach to determining the tropopause is to use tracers of stratospheric or tropospheric air. In the 1950's and early 1960's, atmospheric testing of nuclear bombs injected vast quantities of radioactive debris into the stratosphere. Because of the large thermal stability of the stratosphere, residence times of this radioactive debris ranged from months to years. Many researchers (e.g., Machta and List, 1959; Libby and Palmer, 1960; Reiter, 1963; Reiter and Mahlman, 1965) used these radioactive tracers to examine diffusion and air motion within the stratosphere and between the stratosphere and troposphere. Penn (1964) recognized that ozone, whose primary source is in the stratosphere, could also be used as a tracer of stratospheric air. Currently, potential vorticity, a derived variable combining thermal stability and vorticity, is often used as a tracer of stratospheric air. Potential vorticity is a quasi-conservative quantity which has large values in the stratosphere and small values in the troposphere. Reed (1955), Staley (1957), Reed and Danielsen (1959), Staley (1960), Danielsen (1968) and Shapiro (1976) among others have used potential vorticity to study the intrusion of stratospheric air into the troposphere near well-developed mid-latitude cyclones. Excellent correlations between potential vorticity and the physical tracers ozone and radioactive debris have been shown by Danielsen (1964, 1968), Danielsen et al. (1970) and Danielsen and Mohnen (1977). In recent years the strong correlation between potential vorticity and ozone mixing ratio has been widely investigated in order to carefully determine the location of the tropopause and to study its occasionally folded nature (e.g., Danielsen, 1980; Danielsen and Hipskind, 1980; Shapiro, 1974, 1978, 1980).

On the basis of studies using stratospheric tracers, it has been recognized (e.g., Danielsen and Hipskind, 1980) that the WMO tropopause definition does not always yield a height for a tropopause which is in agreement with the tropopause height one might deduce from a profile of ozone data. Their study points out that if one traces the motion of an air parcel, its classification, as determined by applying the WMO tropopause criteria, can suddenly change from stratospheric to tropospheric without change in ozone mixing ratio. As the ozone mixing ratios are typically very different for troposphere and stratosphere, the WMO definition can create an inconsistency.

The availability of many ozonesondes gathered over the 1960's and 1970's has enabled a study of the relationship between tropopause height and the vertical profile of ozone. The purpose of this study is to show that the altitude in a vertical ozone profile at which ozone, and therefore potential vorticity, begins to increase rapidly is determinable from the temperature profile. A modified tropopause definition based on ozone, yet applied to the local temperature profiles, is developed.

A ten-year set of global twice-daily, radiosonde temperature profiles permits construction of a detailed tropopause climatology using the proposed tropopause definition in the form of an automated computer algorithm. A climatology of the vertical gradient of ozone at the newly defined tropopause is prepared by applying the algorithm to an archived set of ozonesonde temperature profiles.

B. Development of a Modified Tropopause Definition

The discussion that follows is a short summary of the first year's work during the development of a new objective definition of the tropopause. The reader is directed to Roe and Jasperson (1980, 1981) for a complete detailed discussion.

Simultaneous ozone-temperature profiles taken from the AFCRL ozonesonde ascents of the mid-1960's (Hering and Borden, 1964, 1967) and from the World Data Center for Ozone in Toronto, Canada were used to re-evaluate the definition of the tropopause from the viewpoint of stratospheric-tropospheric exchange. Thirty-three time sequences (with durations of 1 to 6 weeks) of daily ozonesonde ascents were chosen from 17 different stations totaling 474 profiles. A substantial increase of ozone with height was found to begin approximately at the level where the ozone mass mixing ratio reached 0.1 to 0.2 $\mu g\ g^{-1}$. It was assumed in this study that the level of significant change in the vertical profile of ozone can be thought of as the lower boundary of stratospheric air.

A set of subjectively determined levels based on the location of the first large ozone increase in the vertical was constructed for the 474 ozonesonde temperature profiles. In 68% of the profiles, the level selected from ozone evidence and the level of the WMO tropopause were the same. For 32% of the profiles, the level of the WMO tropopause was higher than the level chosen subjectively from ozone evidence. Hereafter, the term "subjective tropopause" will refer to the latter level. Examples of discrepancies between WMO and subjective tropopauses are given in Roe and Jasperson (1981).

The conventional tropopause is defined as the lowest level at which the lapse rate decreases to $2^{\circ}C\ km^{-1}$ or less for a thickness of at lease 2 km. An examination of the cases where the WMO tropopause was higher than the subjective tropopause revealed that both the lapse rate and thickness criteria mentioned above, were too strict. To remedy this situation, several new tropopause levels were defined for various combinations of lapse rate and thickness criteria. A lapse rate criterion of $2.8^{\circ}C\ km^{-1}$ over a depth of 1 km resulted in a maximum improvement of from 68% agreement to 89% agreement with the subjective levels.

Further improvement in the new objective scheme of tropopause determination was achieved when it was realized that in some cases the relative change in lapse rate from the troposphere to the stratosphere was the important quantity to measure. Examination of the profiles suggested that a linear change of the temperature gradient criterion from the $2.8^{\circ}C\ km^{-1}$ value (when the average tropospheric lapse rate is $6.5^{\circ}C\ km^{-1}$) to a gradient criterion of $5.0^{\circ}C\ km^{-1}$ (when the tropospheric lapse rate is $10.0^{\circ}C\ km^{-1}$), would produce tropopauses in better agreement with the subjective tropopauses. The temperature gradient criterion was held constant at $2.8^{\circ}C\ km^{-1}$ when the tropospheric lapse rate was less than $6.5^{\circ}C\ km^{-1}$ and held constant at $5.0^{\circ}C\ km^{-1}$ when the tropospheric lapse rate was greater than $10.0^{\circ}C\ km^{-1}$ (an unlikely occurrence in the free troposphere). The thickness criterion remained constant at 1 km. Figures 1 and 2 present the temperature gradient conditions schematically. Figure 1 illustrates the definition of the average tropospheric lapse rate, γ_T. The 2 km layer below a prospective tropopause level was chosen to represent the state of the free troposphere. Figure 2 illustrates the relationship between the proposed gradient criterion and the average tropospheric lapse rate. Also shown is the WMO temperature gradient criterion which is independent of the tropospheric lapse rate. Examples of the use of the new objective criteria are found in Roe and Jasperson (1981). Tropopause levels computed by the new rules given above achieved 95% agreement with the subjective ozone-based tropopause levels.

An independent set of about 300 randomly chosen ozonesonde profiles was examined to see if the rule formation obtained from the original 474 soundings was applicable to other soundings. The percentage of agreement between objectively determined tropopause levels and ozone-based subjective tropopause levels was generally confirmed for the random profiles. In addition, the new algorithm was tested on nearly 8000 standard radiosonde temperature profiles to increase coverage of latitudes and seasons. Results showed that the new algorithm performed well.

Since the new objective tropopause finding algorithm was to be applied to a set of archived twice-daily radiosonde temperature profiles, one could further improve and refine the algorithm by including some form of time continuity checking of tropopause height. A time continuity check was developed and incorporated into the computer algorithm for use with archived data and is described in Roe and Jasperson (1980).

The new tropopause-finding algorithm was applied to a large data set of archived radiosondes. This data set was global and contained over 1000 individual stations of varying record length. The time period covered was from September 1963 through December 1973 and most stations had twice-daily observations.

Approximately 3.1 million tropopauses have been produced and recorded on magnetic tapes. Also, monthly means of pressure, temperature and height of the tropopause and the associated standard deviations have been calculated. On the order of 100,000 monthly means are printed on paper and recorded on magnetic tape. A climatology of the newly-defined tropopause is presented in the following sections of this report.

C. <u>Climatology of the New Tropopause</u>

Figures 3a through 3l present the ten-year tropopause climatology in the form of monthly mean maps. Broken lines in the analysis are extrapolations through areas devoid of data. In order to construct these 12 maps, all tropopauses occurring within the boundaries of 10° latitude by 10° longitude boxes were averaged to yield a single height for each box. A test was made using 5° latitude by 5° longitude boxes to see if too much detail was lost in the use of $10^{\circ} \times 10^{\circ}$ boxes. It was determined that the $10^{\circ} \times 10^{\circ}$ boxes were the best choice to maximize detail yet minimize noise in the analyses. Long-term monthly mean refers to the average of all tropopauses occurring in a particular calendar month throughout the ten-year period of record. Therefore, the individual years are not weighted equally in the mean and data from later years tend to dominate slightly.

The January map, Figure 3a, shows maximum heights above 16 km over the southeast Asian islands, the tropical western Pacific, northern South America, the equatorial Atlantic, and eastern equatorial Africa. Minimum heights below 8 km are found over eastern Siberia, the Sea of Okhotsk, and northern Canada. The northern Atlantic between Greenland and Scandinavia is a region of relatively high tropopause for that latitude, no doubt influenced by the Gulf Stream. The contrast between winter and summer hemispheres is clearly evident in the tropopause height gradients. A band of strong gradients is seen between 20°N and 40°N with longitudinal maxima near Japan and Arabia. Fairly weak gradients are evident throughout the Southern Hemisphere with the highest tropopauses over the warm continents. Regions of extremely large height gradient such as Japan most clearly show the discontinuity between polar and tropical air masses that exists on a day-to-day basis.

The April map, Figure 3d, shows maximum heights above 16 km over a broad belt stretching from western equatorial Africa east to the central Pacific and a small area over the eastern equatorial Pacific east to South America. Minimum heights below 8 km have left Siberia but remain in northeastern Canada and begin to appear in Antarctica at 170°E. The North Atlantic now shows a very strong Gulf Stream influence with a sharp ridge of high tropopauses over Iceland. During this transition season the height gradients are very similar in the subtropical regions of both hemispheres. The gradient over Japan has weakened while the one over Arabia has not changed much and a strong gradient is developing over Australia.

The July map, Figure 3g, shows maximum heights above 16 km confined to southern Asia from the eastern Mediterranean to the Phillipines due to the Asian Monsoon circulation. The high tropopauses have left the tropics almost entirely because the earth is at apogee in its orbit (Gage and Reid, 1981). Minimum heights are seen in eastern Antarctica but not as low as during Arctic winter. Height gradients are quite large between 20°S and 40°S with longitudinal maxima over Australia, the western Pacific, and southeast of Madagascar. In the generally weak gradients of the Northern Hemisphere summer, a region of intense gradient remains over Turkey due to the dramatic intrusion of high tropopauses across Arabia since April.

The October map, Figure 3j, shows maximum heights above 16 km retreating from southwest Asia and returning to the southeast Asian islands and the tropical Pacific. Minimum heights below 8 km are confined to the Ross Sea and areas below 9 km begin to advance over the Russian Arctic and northeastern Canada. An anomalous region of relatively high tropopauses is located in the Weddell sea near Antarctica and will be explained later. The sharp height gradients in the Southern Hemisphere are weakening while those over Japan and Tibet are strengthening in this transition season.

The annual changes in global tropopause height outlined above can be followed more closely by examining each monthly map but space does not permit an individual description of each map here. Crutcher and Davies (1969) present a long-term climatology of WMO tropopause height organized into four seasonal maps. Broad features are similar to the current climatology but there are important differences. The new tropopause definition produces slightly lower tropopauses everywhere as explained in the development phase. Gradients between the polar and tropical tropopauses are enhanced in the new climatology because the new definition is able to identify low polar tropopauses farther into the subtropics than the WMO definition. Arctic winter tropopauses are somewhat lower and more consistent than with the WMO definition which occasionally produces very high Arctic winter tropopauses. The Antarctic winter tropopause is entirely different from the Arctic one. The question of whether a tropopause can be defined at all in the depths of the Antarctic winter (Court, 1942) is still not clearly answered. The current climatology shows the odd feature that the winter tropopause actually appears higher than the summer one in the Antarctic (compare Figures 3h and 3c) which agrees with a summary presented by Murgatroyd and O'Neill (1980). Both polar regions show very clearly marked tropopauses in their respective summer seasons. A typical January Arctic temperature profile has a deep surface inversion (up to 750 mb) followed by a layer of moderate lapse rate to an identifiable low tropopause that ranges from 600 to 300 millibars. A deep, nearly isothermal, layer exists above the tropopause to about 100 millibars and then the temperature decreases steadily to about 30 millibars. On the other hand, a typical August coastal Antarctic temperature profile has a deep surface inversion (up to 750 mb) followed by a very deep layer of gradually decreasing temperature to a low of $-80^{\circ}C$ at 30 millibars. This Antarctic winter profile structure shows no sharp changes in temperature lapse rate and consequently has no obviously apparent tropopause. The concept of tropopause as a thermal discontinuity has no meaning in a profile such as this. Any tropopause rule will simply place the tropopause at a level where the temperature decrease has slowed sufficiently. This level is usually between 200 and 300 millibars, so the Antarctic winter tropopause appears higher than the clearly identifiable summer one at 350 millibars. Therefore, the new definition picks high tropopauses during Antarctic winter just as the WMO does, but not quite as high.

For comparison with the current study, Makhover (1971, 1972, 1979) has presented climatologies of the tropopause for the U.S.S.R., the Northern Hemisphere, and the entire earth respectively. Sastry and Narasimham (1966) presented a climatology of the tropopause over India with special attention to the opposite seasonal behavior of the tropopause height on either side of $20^{\circ}N$. Appu et al. (1980) discussed the Indian tropopause in the larger context of a climatology of the entire atmosphere over India. A short discussion of tropopause variability over Canada was presented by Kantor (1967).

Figures 4a-4l and 5a-5l are monthly frequency distributions of tropopause height for the ten-year period of record, organized by 10° latitude belts. Each figure contains 9 smaller panels, one for every latitude belt of a hemisphere. The ordinate is frequency of occurrence based on the total number of tropopauses and the abcissa is height with a resolution of 0.5 kilometer. The small panels each contain an array of four numbers in the upper left-hand corner. The top entry indicates the latitude belt, the second is the total number of tropopauses, the third is the arithmetic mean tropopause height for the distribution in kilometers, and the bottom entry is the overall space-time standard deviation from the mean, in kilometers. Panels for the latitude belt 80°-90°S for July and September are blank because the number of profiles is so small that a reliable frequency distribution cannot be depicted. The modes from these frequency distributions are depicted in height-latitude cross-sections discussed below. The bi-modal and sometimes even tri-modal nature of the middle latitude tropopause is quite evident in these diagrams. It is fairly easy to follow the seasonal behavior of the polar and tropical tropopauses through the frequency distributions.

Figures 6a through 6d are long-term monthly mean height-latitude cross-sections of the tropopause for January, April, July, and October. U. S. Standard Atmosphere pressures are given at the right for convenience. Three quantities are shown on each diagram. Dots are entered for the mean tropopause height (again, individual years are not equally represented), error bars are entered around each dot for the overall space-time standard deviation, and horizontal lines are entered to show predominant modes taken from the frequency distributions described earlier. The January cross-section shows a fairly standard 2 to 3 leaf structure of the tropopause modes (see, Palmén and Newton, 1969). The Northern Hemisphere shows strong southerly penetration of the polar tropopause which rises from about 8 km at the pole to about 9 km at 40°N. The Southern Hemisphere polar tropopause only penetrates north to 55°S. The transition tropopause modes in the subtropical latitudes of both hemispheres may be somewhat artificial because of the poorly-behaved nature of the frequency distributions (see Figures 4a and 5a). The tropical tropopause mode is consistently higher than the mean indicating a negatively skewed distribution. The April cross-section shows the Southern Hemisphere nearly unchanged from January. The Northern Hemisphere shows little change in the tropics, a retreat northward of the polar tropopause together with an expansion of the middle leaf northward, and a dual mode appears near the pole. The lower mode is due to the sharp minimum in tropopause height that is experienced in Canada (and not at other longitudes) during early spring. The July cross-section shows strong northerly penetration of the Southern Hemisphere polar tropopause to a latitude of about 35°S that occasionally has dual modes. A mode is not entered for the latitude belt 80°-90°S because the frequency distribution was not constructed for the lone 12 soundings that are available. However, the mean and standard deviation for these 12 are entered for completeness. The Antarctic winter tropopause is shown here to be higher than the summer tropopause, a feature that was explained earlier. The Northern Hemisphere polar tropopause has retreated back to almost 70°N with a broad middle leaf extending upward and southward to about 40°N. The most interesting feature is the dual mode throughout the tropics (see Figures 4g and 5g). The original high tropical tropopause mode at 16.5 km is joined by a lower mode at about 14.5 km. During this time of the year the tropical temperature profiles very often have a transition layer between the large lapse rate characteristic of the troposphere and the temperature inversion characteristic of the stratosphere. Slight adjustments of the lapse rate in this transition layer lead to the two modes of tropopause height. The October cross-section is comparable to the April cross-section for opposite hemispheres. The northern polar tropopause has lowered slightly and penetrated a little farther south, the tropical tropopause has almost lost its dual nature and the middle leaf shows its largest extent. The Southern Hemisphere shows a very clear transition from the July to the January cross-section. It must be kept in mind that these cross-sections are simply average pictures of the meridional structure of the tropopause and may bear little resemblance to the day-to-day structure.

In connection with the previous discussion of the average meridional tropopause cross-sections, Figure 7 presents a comparison between the WMO tropopause and the newly defined ozone tropopause. The figure shows long-term monthly mean height-latitude cross-sections of the two tropopauses for January and July. The new definition is consistently lower in the mean than the WMO definition at all latitudes and seasons. It is clear that large differences do not exist since approximately two-thirds of all profiles have the same tropopause level under both definitions. The smallest difference (about 200 meters) in mean height occurs during summer at mid-to-high latitudes. The largest difference (about 1100 meters) in mean height occurs in the sub-tropical regions. This is due to the new definition's ability to detect low tropopauses in association with active synoptic-scale waves that penetrate to sub-tropical latitudes. The lower mean tropopauses in extratropical regions are justified by the ozone evidence.

The mean height difference between the WMO tropopause and the new tropopause in the tropics is due to the frequent occurrence of a transition layer between the strong lapse rate typical of the troposphere and the temperature inversion typical of the stratosphere. The WMO definition is most likely to choose the top of the transition layer while the new definition is most likely to choose the bottom. In contrast to extratropical latitudes, ozone evidence is not generally useful in deciding whether the tropical tropopause should be located at the top, or bottom of the tropical transition layer. Sometimes the ozone increase is located at the top of the layer and sometimes the increase is located well above the layer. There is infrequent deep cyclonic activity in the tropics to bring the ozone down to the troposphere from the stratosphere in contrast to the extratropical latitudes, and apparently, the tropical Hadley circulation acts to keep the ozone about 1 km above the transition layer. Therefore, the assumption that ozone should begin to increase strongly at the tropopause level, valid at the higher latitudes, is not valid in the tropics. The transition layer is often rather thick due mostly to the coarse vertical resolution of data at those levels, especially at non-U.S. stations. So, the height discrepancy in the tropics may be exaggerated.

The standard deviation bars about the mean tropopause heights presented in Figures 6a through 6d contain variability of several types. They contain day-to-day variability within a single month, year-to-year variability of that month, and longitudinal variability around a latitude belt. The first of these dominates the overall standard deviation. The longitudinal variability for 7 latitude belts from 10°N to 80°N is presented separately in Table 1. The longitudinal variability was determined from the 36, 10°-latitude by 10°-longitude box means of tropopause height in each latitude belt that were used to draw the monthly maps presented earlier. If a box contained no data, then a value was interpolated for it from the hand-analyzed maps so that each belt contained 36 heights. Latitude belts other than the 7 presented in Table 1 contained too many missing boxes for meaningful interpolation and therefore, no attempt was made to quantify the longitudinal variability. A qualitative appreciation of the longitudinal variability at most latitudes can be gained by simply viewing the 12 maps.

A short note about the space-time distribution of the 3.1 million tropopauses used for this climatology is in order. Table 2 presents the space-time distribution organized by latitude belt and year for four of the twelve months. Note that October starts with the year 1963 since the archived radiosondes span the period September 1963 through December 1973. The paucity of Southern Hemisphere data is glaringly evident, especially at higher latitudes and earlier years. This fact should inspire caution in using some of the Southern Hemisphere tropopause climatology. The Northern Hemisphere appears well covered by data but only in a latitudinal sense. It must be kept in mind that vast ocean areas with nearly no data are included in these zonal numbers. The change of data coverage during the ten-year period is small for low and high latitudes and somewhat large for middle latitudes. This table gives one an idea of how much the later years dominate the long-term means at each latitude when the years are not weighted evenly.

D. Stratospheric Seasonal Mass Variation

The stratosphere is contained between its lower boundary, the tropopause, and its upper boundary, the stratopause. Both of these boundaries move up and down in response to seasonal forcing. The change of stratospheric mass from one seasonal extreme to the other is essentially totally controlled by the movements of the tropopause. Seasonal changes of the stratopause height contribute negligibly to changes in stratospheric mass when compared to seasonal changes of the tropopause height because the vast majority of stratospheric mass resides in the lower stratosphere. The seasonal change in hemispheric stratospheric mass is due to two processes: the actual exchange between troposphere and stratosphere in one hemisphere, and exchange of stratospheric air from one hemisphere to the other. Only the resultant net change in stratospheric mass may be calculated from the tropopause climatology. Figure 8 shows a pressure-latitude cross-section of the tropopause for both hemispheres. These curves represent the long-term monthly mean tropopause pressures for each 10°-wide latitude zone for February and August. Each long-term monthly mean is equally weighted by year. The construction of the vertical and horizontal scales of the diagram is such that the area is directly proportional to atmospheric mass. It is easy to see that the hemispheric stratospheric mass is at a maximum in late winter and a minimum in late summer. The middle-latitude seasonal change due to the seasonal migration of the polar jet stream is larger than that at other latitudes. The adjustment in the tropics is symmetric about the equator and due to the annual cycle of sun-earth distance. The variation in the south polar region is opposed to the rest of the southern hemisphere and, in fact, in phase with the north polar regions due to the unclear nature of the tropopause during the south polar winter as discussed earlier. Danielsen (1975) presents a similar diagram for the Northern Hemisphere for one particular year, 1958 for comparison.

From the tropopause climatology the stratospheric mass for each 10°-wide latitude belt and each month was calculated. For convenience, the stratopause surface was taken as constant in space and time and located at a height of 50 kilometers and a pressure of 0.8 millibar. Atmospheric mass above the troposphere for each 10°-wide latitude belt was calculated by multiplying the tropopause pressure by the surface area of that latitude belt and dividing by the acceleration of gravity. The stratospheric mass was obtained by subtracting the atmospheric mass above the stratopause which amounts to about 0.5% of the atmospheric mass above the tropopause. Therefore, even large variations from the constant stratopause pressure assumed in this study, do not significantly affect the calculation of stratospheric mass. Table 3 presents the seasonal change of stratospheric mass due to the seasonal adjustment of the tropopause pressure by latitude. Each table entry consists of three numbers, the long-term (weighted equally by year) monthly mean, the interannual standard deviation, and the number of years available for that month and latitude belt. The means and standard deviations must be multiplied by 10^{16} to be expressed in kilograms of stratospheric air. The largest percentage changes of stratospheric mass occur in the 30^{o}-40^{o} latitude belts where the seasonal shift from polar to tropical circulations is greatest. Staley (1962) presented some figures on the percentage change of stratospheric mass for four individual stations at various latitudes during the year 1957. His figures closely correspond to percentages that may be deduced from Table 3 in this study.

Figure 9 shows the hemispheric and global seasonal changes of stratospheric mass. The graph for the Northern Hemisphere was obtained by simply adding up each latitude's contribution to the hemispheric total for each month from Table 3 utilizing either 10 or 11 years of data. The graph for the Southern Hemisphere however, was obtained by taking only the last 7 years of data (1967-1973) so that latitudes and years are equally weighted statistically. The 80^{o}-90^{o}S latitude belt required the addition of some data to complete the 7 years. This was done by substituting existing means for some missing years. Since this region only contributes about 2% of the hemispheric total mass, the data additions should contribute negligible error to the figure. The graph for the entire globe was obtained by adding the two hemispheres for the period 1967-1973 only. Error bars on all three curves are the interannual standard deviations. It is seen that the Northern Hemisphere stratospheric mass is approximately 50 x 10^{16} kg and varies seasonally by 21% of this value from February to August. Danielsen (1975) cited values of 45 x 10^{16} kg for the mass with a seasonal variation of 22%. Neither of these seasonal percentage changes of Northern Hemisphere stratospheric mass are in agreement with Reiter (1975) who calculated 42.6×10^{16}kg for the mass and about 10% seasonal variation for the year 1963. It must be kept in mind that Reiter's calculations are only for a single year and only include tropopauses selected from the North American longitude sector, while the current study includes 10 years of data from all longitudes. About half of the discrepancy with the current study may be attributed to the lack of seasonal adjustment reported by Reiter (1975) north of 55^{o} latitude. A minor discrepancy with the current study is the location of the latitude where the change of stratospheric mass from winter to summer changes sign. In the current study the latitude is between 15^{o}N and 20^{o}N (see figure 8) while in Reiter (1975) the latitude is about 25^{o}N. Figure 9 also shows that the Southern Hemispheric stratospheric mass is approximately 51×10^{16}kg with a seasonal variation of 10%. The global stratospheric mass is then approximately 101×10^{16}kg with seasonal variation of 5%, in phase with the Northern Hemisphere. The seasonal change of stratospheric mass is twice as large in the Northern Hemisphere principally because the land-sea contrasts which enhance seasonal variation are much larger than in the Southern Hemisphere. Table 3 and Figures 8 and 9 present a concise climatology of the seasonal adjustment of stratospheric mass.

E. <u>Long-Period Variation of Stratospheric Mass</u>

This section attempts to detect any organized long-period variation in the stratospheric mass or, equivalently, the tropopause pressure. The term long-period refers to any time scale longer than one year, so year-to-year changes in stratospheric mass (tropopause pressure) from 1963 through 1973 are of interest.

The quasi-biennial oscillation (QBO) of stratospheric zonal winds in the tropics is an obvious long-period variation to investigate with regard to tropopause pressure. The QBO index used in this study is the 30-millibar zonal wind at Howard AFB in the Canal Zone (9^{o}N) for the period September 1963 through December 1973. The QBO time series consists of each month's zonal wind deviation from the long-term mean for that month, thereby removing the annual and semi-annual cycles to leave only the QBO and noise. This QBO time series was lag-cross correlated with 31 time series involving either stratospheric mass or tropopause pressure. Each time series covered the same period (9/63-12/73) and was constructed from the monthly deviations from the long-term monthly means just as the QBO time series was constructed. The 31 dependent time series were the stratospheric mass in the 18 latitude belts from pole to pole, 5 individual stations' tropopause pressures along the 80°W meridian, and 8 other individual stations' tropopause pressures located in the tropics. The 13 individual stations used are listed in Table 4. Lag-cross correlations were performed between the QBO time series and each of the 31 tropopause time series for lags of -30 to +30 months, where negative lag refers to the QBO series lagging the tropopause series. The overall correlation results were not impressive. Of the nearly 1900 correlation coefficients computed, none was larger than 0.39. The two latitude belts nearest the equator (0°-10°N and 0°-10°S) showed weak positive correlations of 0.3 at lags of 6 to 7 months. Positive correlations imply that the tropopause is highest during the easterly phase of the QBO. The 6 to 7 month lag of the tropopause correlation may be related to the speed of the downward propagation of QBO phase from the 30-millibar level to the tropopause level, a distance of approximately 7 kilometers. The phase of the QBO is known to propagate downward with a velocity of about 1 kilometer per month. The low correlation coefficient of 0.3 is not convincing for a physical connection. The tropical QBO in the wind shows essentially no correlation with the middle latitude stratospheric mass in either hemisphere. A weak correlation of between -0.3 and -0.4 appears between the QBO and the high latitude stratospheric mass (70°-80°N and 70°-80°S) at lags of a few months. This implies that the high latitude tropopause is highest during the westerly phase of the QBO, in contrast to the low latitude tropopause. Again, the magnitude of the correlation coefficents is small. Of the individual stations only Cape Kennedy, Kwajalein and Ponape showed correlations larger than 0.25. Kwajalein and Ponape have positive correlations with lags of a few months while Cape Kennedy has a negative correlation with a lag of a few months.

The results above do not agree well with a similar study by Angell and Korshover (1974). In the tropics they presented a correlation of 0.8 between the QBO in the wind and the QBO in the tropopause pressure, in the same sense as the current study, but much larger. A large negative correlation of -0.7 between the QBO in the tropical tropopause pressures and the QBO in the temperate tropopause pressures was presented that, again, is in the same sense as the current study but much larger.

Several important differences exist between the current study and that by Angell and Korshover that may not allow close comparison of results. Their data spanned a longer time period, 1957-1971; where there were multiple WMO tropopauses, they used the coldest (and thus highest) one; they used the 50-millibar zonal wind as a QBO index; and they employed a band-pass filter on the monthly mean tropopause pressures (the 12-month running mean minus the 30-month running mean). The current study is based on the period 9/63 through 12/73, uses the first tropopause given by the new algorithm (if more than one exists), uses the 30-millibar zonal wind as a QBO index, and utilizes the monthly deviations of tropopause pressure from the long-term monthly means rather than running means.

Angell and Korshover also showed an overall long-term <u>increase</u> in tropopause <u>pressure</u> during the period 1957-1970 at all of their individual stations with a magnitude of several millibars per decade that is largest in the tropics. In the current study the zonal mean tropopause heights were investigated for the existence of long-term trends during the period 1963-1973. Results for the two latitude belts 0^{o}-10^{o}N and 0^{o}-10^{o}S are presented in Figures 10a and 10b. Plotted for each month are the annual deviations of tropopause height from the long-term monthly means for the period of record. The figures show that for the belt 0^{o}-10^{o}N all months show a long-term increase of tropopause height from 1963-1973 with slopes ranging from 100 meters per decade in February to 790 meters per decade in June. This corresponds to a long-term <u>decrease</u> of tropopause <u>pressure</u> of from 2 to 13 millibars per decade. Curiously, the figures show that for the belt 0^{o}-10^{o}S most months show a long-term decrease of tropopause height from 1963-1973 with slopes as high as 880 meters per decade (15 millibars per decade). Overall, in the Northern Hemisphere the latitudes from 0°-30°N show increases of tropopause height with time while the latitudes from 30°-90°N generally show decreases of tropopause height with time. The Southern Hemisphere generally shows decreases of height from 1963-73 for 0°-10°S, 20°-40°S, and 60°-80°S and essentially no trend for the remaining latitudes. A serious discrepancy in long-term trend of tropopause height between the current study and Angell and Korshover appears only in the Northern Hemisphere tropics. The period 1957-1964 is responsible for most of the trend found by Angell and Korshover. After 1964 (when the current study starts) there appears to be little or no trend in their tropopause pressures. It should be pointed out that Angell and Korshover's tropical tropopause trend was based on 8 individual stations between 3°S and 35°N while the current study is based on zonal means between 10°S and 10°N containing 63 stations. Their 8 stations were combined to form 3 time series.

Solar-terrestrial effects might be another long-period variation to look for in the tropopause climatology. Recently, Gage and Reid (1981) claimed to have found significant positive correlations between the sunspot number and the annual average height of the tropical tropopause during the period 1952-1973. Earlier investigators such as Stranz (1959) and Cole (1975) have also reported positive correlations with the tropical tropopause height. Gage and Reid (1981) proposed a physical mechanism to explain the correlation due to the variation of surface insolation in the tropics during the 11-year solar cycle. The current tropopause study was not able to convincingly demonstrate a correlation between sunspot activity and tropopause height. A few stations in the tropical Pacific, such as Kwajalein, do show a slight upward trend in the 12-month running means of tropopause height from 1963 to 1970 but no detectable decrease from 1970 to 1973. Two problems make it difficult to detect any solar cycle correlations in the current study. First, the data only span 10.3 years which makes it difficult to look for an 11-year cycle and second, Solar Cycle 20 (1965-76) had a very low amplitude.

Finally, the behavior of the tropopause was investigated before, during and after two major stratospheric sudden warming events. The first was during February 1966 and is described in detail in Quiroz (1969). This sudden warming event was most pronounced in the eastern hemisphere so two stations from the Russian Arctic region were chosen for investigation, Ostrov Vize (80°N, 77°E) and Turukhansk (66°N, 88°E). The time series of their twice daily tropopauses for the two-month period, January-February 1966, was examined. No organized pattern of tropopause behavior was detected during these two months. The second warming event took place at the end of December 1967 and is described in detail in Johnson (1969). This event was most pronounced in the eastern Canada-western Greenland area so two stations from this region were chosen for investigation, Thule (77°N, 69°W) and Eureka (80°N, 86°W). The time series of their twice-daily tropopauses for the two month period, December 1967-January 1968, was examined. Again, no organized pattern of tropopause behavior was detected. Investigation of this second warming event was hampered by missing data during the last phase of the dramatic warming. Four other Canadian stations in the vicinity all had missing data during this period but the first phase of the warming event showed no unusual behavior at the tropopause.

The absence of a connection between tropopause height variations and stratospheric sudden warmings is not too surprising since the major features of the warmings occur above the 30-millibar level while the tropopause is located near 400 millibars during the Arctic winter. This does not mean that the total stratospheric mass remains unchanged during a warming event. It may change due to air density changes in the middle stratosphere and/or very large changes in the stratopause height caused by the warming. These effects are beyond the scope of this research effort.

F. Application of Algorithm to Ozonesondes

It was of interest to examine the climatology of the vertical gradient of ozone at the newly defined tropopause. This climatology could allow an estimation of diffusion of ozone at the new tropopause on scales of 10°-latitude zonal means, months, and 500 meters in altitude which is the typical vertical resolution of standard ozone profiles. A body of approximately 8000 ozonesonde ascents containing simultaneous ozone-temperature profiles from 49 stations was available for processing. These ozonesonde stations had many different periods of record but the entire set spanned the years 1962 through 1980. The 474 profiles used to develop the new tropopause algorithm are included as a subset of the 8000 total ozonesondes. Unfortunately, most of the data were in the Northern Hemisphere and much of that in the middle latitudes. Therefore, a true global climatology of vertical ozone gradients at the tropopause was not possible.

The new tropopause algorithm that was developed for the ten-year radiosonde data set discussed earlier was applied to all of the ozonesondes with one difference. The forward and backward time continuity adjustment of tropopause height that was applied to the radiosonde data set was not used in processing the ozonesonde data set. This is because the ozonesondes are not uniformly spaced in time for a typical month of data as was the case for the radiosondes. Often the ozonesondes are spaced one week apart within the month so that a time continuity check becomes unreliable. The individual tropopauses calculated from the 8000 ozonesondes were recorded on magnetic tape. Also, monthly means of pressure, temperature and height of the tropopause and the associated standard deviations have been calculated. On the order of 2000 monthly means were printed on paper and recorded on magnetic tape.

G. Calculation of Vertical Ozone Gradients

The question arises as to how to define the vertical gradient of ozone at the new tropopause. It seems there are two basic approaches. Nastrom (1977) estimated the gradient of ozone at the tropopause by finite differences of mean values of ozone mixing ratio in atmospheric layers above and below the tropopause. The other approach, taken in this study, is to estimate the mean ozone gradient in the layer of stratospheric air immediately above and in contact with the tropopause. If one assumes there is no convergence or divergence of ozone flux in the vicinity of the tropopause, then the downward flux of ozone due to diffusion in the lowest layer of the stratosphere will be equal to the downward flux of ozone through the tropopause. If one relies on K-theory to estimate the diffusion of ozone in the vicinity of the tropopause, then the assumption of a vertical diffusion coefficient, K_z, for the same scale is critical. It is generally believed (see e.g. Gudiksen et al., 1968; Reed and German, 1965) that K_z is strongly dependent on the vertical stability of the atmosphere. Therefore, it is possible to assign characteristic K_z's to the lower stratosphere and upper troposphere which are very different in magnitude, but it is not easy to assign a K_z to the boundary between these two very different air masses. This study estimates the diffusion of ozone across the tropopause by calculating the vertical ozone gradients in a layer of stratospheric air just above the tropopause and by assuming a K_z that is characteristic of diffusion in stable stratospheric air.

The choice of the thickness of the layer above the tropopause to be considered for calculation of vertical ozone gradients cannot be smaller than the typical vertical resolution of the non-AFCRL ozonesondes, approximately 0.5 kilometer. The average vertical ozone gradient was computed for each of six overlapping stratospheric layers in contact with the tropopause (0.5, 1.0, 1.5, 2.0, 2.5, 3.0 km) and also for the comparable six upper tropospheric layers below the tropopause. The layers thicker than 0.5 kilometer are presented for the convenience of others who may wish to use a coarser vertical resolution. A limited climatology of the vertical ozone gradients both above and below the newly defined tropopause was constructed.

Since the ozonesonde data coverage in the Southern Hemisphere was so sparse and sporadic, the climatology of ozone gradients was limited to the eight 10^{o}-wide latitude belts from the equator to 80^{o}N using 37 of the original 49 stations. Tables 5a and 5b present the ozone gradient climatology. They are divided into the eight latitude belts and twelve months of the year. The first column of figures labelled N, to the right of the month, is the total number of ozonesonde flights available for that month and latitude belt including all years of observation. Note that the latitude belt, 10^{o}-20^{o}N, has almost no observations and certainly is not a reliable "zonal mean" but was included here for completeness. The reliability of the ozone gradients presented in these tables is highly dependent on N. The next six columns of figures are the vertical ozone gradients below the tropopause for the six layer thicknesses described above. The final six columns of figures are the vertical ozone gradients above the tropopause for the six layer thicknesses. Each entry of Table 5a must be multiplied by a factor of 10^{-9} so that the resulting ozone density gradients have units of kg m^{-3} per kilometer. Table 5b presents the same information as Table 5a but its entries must be multiplied by a factor of 10^{-6} so that the resulting ozone mass mixing ratio gradients have units of g g^{-1} per kilometer. Positive values of the vertical ozone gradient refer to an increase of ozone concentration with height. The tables clearly show the step-like increase in ozone gradient at the tropopause. The middle latitudes in summer typically show a four to five fold increase in ozone gradient values across the tropopause. The gradients above the tropopause are maximum in the late spring and early summer and minimum in the fall season. Tropical latitudes show essentially zero gradient below the tropopause and a weak positive gradient above due to the observed fact that the first large increase in ozone concentration in the vertical often occurs well above the tropopause in these latitudes. Middle and upper latitudes show weak-to-moderate positive gradients below and quite large positive gradients above the tropopause. Table 5b compares closely to ozone mass mixing ratio gradients derived from typical ozone profiles for different latitudes given in Dütsch (1974).

Another way to organize the ozone gradient data appears in Tables 6a-6h and 7a-7h which are frequency distributions of the data. The first eight tables (Tables 6a through 6h) refer to vertical ozone gradients above the tropopause (one for each latitude belt) while the last eight (Tables 7a through 7h) refer to the vertical ozone gradients below the tropopause. Each table contains 72 frequency distributions: 6 layer thicknesses for 12 months, for the particular latitude belt identified at the top. The frequency entries represent the percentage of N total gradients (given at the extreme right) that fall into each gradient category shown at the top of each column. The gradient categories for all 16 tables are given in ozone density units. For example, the column headed "200" contains all vertical ozone gradients that are greater than or equal to 150×10^{-9} kg m^{-3} per kilometer but less than 200×10^{-9} kg m^{-3} per kilometer. The two most striking features of the frequency distributions above the tropopause are the movement of the mode toward larger gradients with increasing latitude and, the broadening of the distributions in late spring to early summer especially at middle and high latitudes. The two most striking features of the frequency distributions below the tropopause are the relative stability of the mode just to the positive side of zero gradient and the significant broadening of the distributions from low latitudes to high latitudes. The tables of mean ozone gradients and the tables of the ozone gradient frequency distributions support the aim of this study that the newly-defined tropopause should be very closely related to the location of the first large ozone increase in the vertical. This is true everywhere but in the tropics where the ozone is typically found at a distance above the tropopause as explained in the earlier section on tropopause climatology.

H. Estimation of Diffusion at the Tropopause

It is possible to arrive at an estimate of the diffusion at the tropopause on the scales used here, by applying K-theory to the climatology of ozone gradients presented in the previous section. The literature has many different estimates for the vertical eddy diffusion coefficient, K_z. Since K_z is not a real property of the atmosphere but rather a device to parameterize eddy motions below the smallest scale resolvable by a particular atmospheric model, estimates for it depend not only on time and space but also on the physical model that one assumes for the atmospheric motion under study. As K_z is a strong function of stability, it has a large range of values. For example, Dickinson et al. (1975) compiled estimates of K_z that have been used in modeling the vertical transfer of atmospheric tracers. In the lower stratosphere these ranged from 10^3 to 10^5 cm^2 sec^{-1}. Other investigators (e.g. Reed and German, 1965; Gudiksen et al., 1968) gave detailed estimates of K_z as a function of altitude, latitude and season that range from 10^3 to 4×10^4 cm^2 sec^{-1}. Cunnold et al. (1975) presented a detailed three-dimensional model of ozone where a constant K_z equal to 4×10^3 cm^2 sec^{-1} was used in the lower stratosphere, modified from estimates given in Wofsy and McElroy (1973). The most important consideration in choosing a value for K_z is the scale of motion that one is trying to describe. Cunnold et al. (1975) recognized, for instance, that in the Wofsy and McElroy calculations, K_z represented the effect of all motions. However, Cunnold et al. only wanted to model transport by motions smaller than those being explicitly forecast. They concluded that smaller values of K_z, such as 10^2 cm^2 sec^{-1}, may be more appropriate in the region of the tropopause. Cunnold et al. (1980) used K_z equal to 10^2 cm^2 sec^{-1} in a model almost identical to the 1975 model.

In the current study, diffusion at the tropopause was estimated from the vertical ozone gradients for the 0.5 kilometer layer above the tropopause (Table 5a). To complete diffusion estimates for the entire Northern Hemisphere, ozone gradients for the zone 10^o-20^oN were interpolated from the zones 0^o-10^oN and 20^o-30^oN, while ozone gradients for the zone 80^o-90^oN were taken from those at 70^o-80^oN. Two values of K_z were used to give a range of estimates for the diffusion. When K_z was set at a constant 10^2 cm^2 sec^{-1}, the Northern Hemisphere diffusion ranged from a low of 74 kg sec^{-1} in October to a high of 215 kg sec^{-1} in June. If one were to assume similar conditions in the Southern Hemisphere, the global annual mean diffusion would be 260 kg sec^{-1}. When K_z was set to a constant 4 x 10^3 cm^2 sec^{-1}, the Northern Hemisphere diffusion ranged from a low of 2950 kg sec^{-1} in October to a high of 8600 kg sec^{-1} in June. The global annual mean diffusion would be 10,400 kg sec^{-1}. Under very different methods of estimation, Nastrom (1977) arrived at a global annual mean of 700 kg sec^{-1}. In their three-dimensional model of ozone Cunnold et al. (1980) estimated about 3000 kg sec^{-1} for the vertical diffusion near the tropopause. Clearly, estimates of the diffusion at the tropopause vary widely and all are critically dependent on how one approaches the definition of K_z. In this study the ozone gradients at the tropopause, given in Tables 5a and 5b, are much more reliable than the estimates of the diffusion.

III. SUMMARY AND CONCLUSIONS

The location of the tropopause, separating stratospheric from tropospheric air masses, has been a subject of much investigation in the past 25 years. No one strict definition in terms of temperature can be applied in all cases. Much of the time there is a clear change in stability between the troposphere and stratosphere and a tropopause may be easily recognized. In some cases, it is very difficult to locate any such feature in a temperature profile. Often the problem under investigation dictates how the tropopause should be defined.

This study defines the stratosphere and tropopause by use of ozone gradient information. A modified WMO tropopause definition that is consistent with ozone evidence, yet defined in terms of temperature profiles alone, has been developed.

A data set of 33 daily sequences, totaling 474 detailed simultaneous ozone-temperature profiles, was used to develop the new tropopause algorithm. The conventional WMO tropopause definition yielded agreement 68% of the time with a set of ozone-based subjectively determined tropopauses. The other 32% of the profiles yielded WMO tropopauses that were too high in light of the ozone evidence. In that same data sample, the new tropopause algorithm yielded agreement 95% of the time with the set of subjective ozone-based tropopauses. From this, one can infer excellent agreement with tropopauses that are based on potential vorticity or radioactive tracers because of the high correlations shown among ozone, potential vorticity and radioactive debris.

The greatest day-to-day discrepancy between the WMO tropopause and the new scheme occurs in the baroclinic zones where active synoptic-scale waves are important. In these regions, the new scheme produces substantially lower tropopauses than the WMO definition, especially within strong low pressure troughs. The newly defined tropopauses are much more consistent with the location of the first large ozone increase in the vertical than are the WMO defined tropopauses.

In the tropics, neither the WMO nor the new tropopause definition usually coincides with the first large ozone increase in the vertical. Typically, this large increase is located well above the tropopause level as determined from the temperature profile and is presumably due to the Hadley circulation and the lack of a large-scale mechanism to bring the ozone down to the troposphere.

The new tropopause algorithm has been applied to a ten-year global set of radiosondes for the purpose of constructing a detailed climatology in the form of maps, tables, cross-sections and frequency distributions. The new climatology was used to estimate the seasonal change and the year-to-year variability of stratospheric mass.

The tropopause algorithm was also applied to about 8000 ozonesonde-temperature profiles in order to construct a limited climatology of vertical ozone gradients at the tropopause in the Northern Hemisphere. Diffusion at the tropopause was estimated from the ozone gradient climatology.

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Latitude	January	April	July	October
10^{o}-20^{o}N	980	728	486	426
20^{o}-30^{o}N	1160	741	884	829
30^{o}-40^{o}N	716	411	918	851
40^{o}-50^{o}N	723	524	543	562
50^{o}-60^{o}N	695	522	299	566
60^{o}-70^{o}N	627	379	346	346
70^{o}-80^{o}N	450	346	232	207

Table 1. The longitudinal standard deviation of tropopause height in meters for 7 latitude belts and 4 months computed from the long-term monthly mean maps of tropopause height, Figures 3a-31.

YEAR	80-90N	70-80N	60-70N	50-60N	40-50N	30-40N	20-30N	10-20N	0-10N	0-10S	10-20S	20-30S	30-40S	40-50S	50-60S	60-70S	70-80S	80-90S
									JANUARY									
1964--	100	490	1558	2829	2806	1962	408	202	24	26	0	1	0	0	0	0	0	0
1965--	169	992	2550	4462	3662	2824	612	590	162	39	0	0	0	0	0	0	0	0
1966--	222	1302	3338	5676	4895	3424	1118	768	201	75	0	0	0	0	0	0	0	0
1967--	194	1250	3471	6176	5750	4028	1200	769	293	81	105	58	112	129	57	4	7	0
1958--	194	1298	3350	6348	6457	3778	1004	686	286	96	76	101	223	115	56	18	44	3
1969--	211	1411	3643	7041	5701	4352	1575	915	330	95	125	200	375	180	67	28	42	14
1970--	219	1465	3790	7373	6153	6011	1817	1110	437	101	198	346	554	211	102	149	81	51
1971--	228	1501	4071	7147	6817	5729	2461	1111	571	188	212	403	722	277	104	228	103	41
1972--	197	1296	3684	6642	6153	5084	2207	1177	543	189	260	478	780	314	83	270	131	53
1973--	183	1577	4499	8439	7615	4849	1664	1120	549	181	230	414	694	283	80	286	129	63
									APRIL									
1964--	27	129	384	621	603	438	95	64	6	3	0	0	0	0	0	0	0	0
1965--	216	1273	3166	5497	4608	3430	1086	717	195	45	0	0	0	0	0	0	0	0
1966--	204	1194	3109	5207	4408	2976	991	764	245	45	0	0	0	0	0	0	0	0
1967--	179	1207	3439	6115	5584	3622	1398	713	246	72	125	175	297	107	29	3	8	0
1968--	198	1440	3629	6844	5698	4096	1483	991	310	106	115	169	343	141	48	31	26	6
1969--	173	1343	3679	6931	5378	3901	1460	908	294	79	152	237	423	173	63	18	17	[illegible]
1970--	213	1496	3946	7383	6407	6133	1940	964	445	110	200	373	631	228	74	121	47	2
1971--	221	1498	4101	7284	6821	5493	2199	986	472	141	262	457	854	287	99	192	72	7
1972--	224	1503	4083	7228	6644	5471	2151	1150	624	205	269	513	829	303	68	235	84	7
1973--	166	1661	5173	9709	8411	5466	2038	1194	494	176	313	546	819	279	82	154	62	0
									JULY									
1964--	220	1177	2921	5121	4211	2723	806	722	158	86	0	0	0	0	0	0	0	0
1965--	219	1290	3143	5639	4631	3046	967	798	260	37	0	0	0	0	0	0	0	0
1966--	210	1364	3521	6302	4844	2970	939	864	287	55	46	146	141	22	0	0	0	0
1967--	231	1569	3699	6828	5888	3764	1443	968	380	118	185	363	500	197	46	22	14	0
1968--	204	1474	3646	6966	5480	3527	1157	991	291	124	147	243	314	139	56	15	19	5
1969--	226	1563	3903	7262	5771	3950	1605	1166	413	130	197	412	555	194	88	28	20	0
1970--	204	1405	3632	7171	5904	4165	1770	1038	543	147	212	449	578	190	25	112	46	2
1971--	236	1537	4127	7253	[illegible]	4339	2143	1150	610	229	301	628	862	265	76	226	79	4
1972--	172	1494	4141	7316	[illegible]	3003	2045	1228	662	248	308	598	786	280	52	212	72	1
1973--	193	1851	5198	9886	[illegible]	4086	1747	1142	617	227	390	612	857	280	61	176	59	0
									OCTOBER									
1963--	113	414	1630	3177	3393	2677	580	336	25	58	0	0	0	0	0	0	0	0
1964--	190	1049	2757	4821	4095	2890	805	609	175	61	0	0	0	0	0	0	0	0
1965--	221	1250	3022	4924	4462	3301	936	699	152	50	0	0	0	0	0	0	0	0
1966--	214	1356	3433	5889	5015	3257	916	635	371	85	108	128	232	67	9	13	11	0
1967--	207	1456	3723	6506	5882	3721	1164	966	384	84	151	264	459	194	86	31	17	7
1968--	211	1422	3676	7066	5814	4001	1268	925	333	100	150	246	476	181	66	19	34	10
1969--	211	1416	3714	6994	5901	4546	1641	1080	421	132	184	364	652	248	101	75	33	6
1970--	210	1431	3941	7436	6395	4774	1703	1098	419	136	204	396	698	241	95	162	87	4
1971--	225	1533	4348	7504	6939	5246	2154	1106	647	162	330	540	910	343	139	341	144	43
1972--	179	1554	4294	7564	7261	5688	2196	1233	677	209	268	536	850	325	69	286	120	22
1973--	199	1874	5236	9621	8254	4706	1772	1142	570	216	348	513	816	300	117	229	58	2

Table 2. Latitude belt by year breakdown of the total number of tropopauses available for climatological study for 4 of the 12 months.

NORTHERN HEMISPHERE

	0-10N MEAN	0-10N SD	0-10N N	10-20N MEAN	10-20N SD	10-20N N	20-30N MEAN	20-30N SD	20-30N N
JAN	4.90	.22	10	5.45	.39	10	7.54	.29	10
FEB	4.89	.20	10	5.34	.25	10	7.68	.40	10
MAR	4.83	.18	10	5.32	.24	10	7.52	.30	10
APR	4.89	.24	10	5.37	.24	10	7.08	.18	10
MAY	5.06	.15	10	5.32	.23	10	6.14	.26	10
JUN	5.43	.25	10	5.49	.16	10	5.38	.23	10
JUL	5.55	.21	10	5.73	.15	10	5.31	.18	10
AUG	5.62	.19	10	5.71	.11	10	5.34	.20	10
SEP	5.55	.22	11	5.60	.15	11	5.20	.20	11
OCT	5.22	.21	11	5.32	.16	11	5.43	.24	11
NOV	4.99	.20	11	5.21	.14	11	5.98	.17	11
DEC	4.83	.12	11	5.31	.15	11	6.75	.27	11

	30-40N MEAN	30-40N SD	30-40N N	40-50N MEAN	40-50N SD	40-50N N	50-60N MEAN	50-60N SD	50-60N N
JAN	9.42	.29	10	8.82	.22	10	7.50	.29	10
FEB	9.64	.36	10	8.95	.21	10	7.71	.21	10
MAR	9.21	.20	10	8.68	.20	10	7.51	.20	10
APR	8.37	.23	10	8.19	.16	10	7.33	.14	10
MAY	7.66	.21	10	7.60	.13	10	6.89	.14	10
JUN	6.81	.17	10	7.26	.21	10	6.40	.12	10
JUL	5.70	.14	10	7.03	.18	10	6.23	.12	10
AUG	5.61	.19	10	6.93	.14	10	6.23	.08	10
SEP	6.30	.26	11	7.16	.22	11	6.38	.12	11
OCT	7.44	.18	11	7.48	.15	11	6.63	.13	11
NOV	8.34	.27	11	8.08	.19	11	7.24	.16	11
DEC	9.03	.29	11	8.67	.22	11	7.46	.18	11

	60-70N MEAN	60-70N SD	60-70N N	70-80N MEAN	70-80N SD	70-80N N	80-90N MEAN	80-90N SD	80-90N N
JAN	5.81	.17	10	3.69	.15	10	1.25	.09	10
FEB	5.88	.19	10	3.65	.13	10	1.26	.07	10
MAR	5.89	.14	10	3.74	.19	10	1.30	.10	10
APR	5.91	.20	10	3.83	.18	10	1.39	.14	10
MAY	5.63	.11	10	3.76	.05	10	1.34	.04	10
JUN	5.21	.11	10	3.53	.07	10	1.24	.03	10
JUL	4.91	.12	10	3.27	.07	10	1.18	.03	10
AUG	4.89	.10	10	3.27	.10	10	1.14	.03	10
SEP	5.10	.10	11	3.33	.06	11	1.17	.03	11
OCT	5.39	.13	11	3.52	.10	11	1.21	.03	11
NOV	5.73	.15	11	3.62	.08	11	1.23	.06	11
DEC	5.75	.14	11	3.60	.14	11	1.26	.08	11

SOUTHERN HEMISPHERE

	0-10S MEAN	0-10S SD	0-10S N	10-20S MEAN	10-20S SD	10-20S N	20-30S MEAN	20-30S SD	20-30S N
JAN	5.19	.41	9	5.11	.35	7	6.64	.23	7
FEB	5.32	.34	9	5.05	.22	7	6.57	.21	7
MAR	5.06	.34	9	5.02	.23	7	6.72	.43	7
APR	4.96	.19	9	5.05	.11	7	6.48	.16	7
MAY	5.13	.18	9	5.29	.10	8	7.23	.53	8
JUN	5.49	.21	9	5.48	.09	8	7.51	.34	8
JUL	5.73	.28	9	5.46	.10	8	7.72	.35	8
AUG	5.69	.16	9	5.72	.15	8	7.66	.34	8
SEP	5.67	.19	9	5.55	.23	8	7.48	.49	8
OCT	5.37	.20	9	5.46	.11	8	7.29	.39	8
NOV	5.17	.19	9	5.21	.19	8	6.86	.43	8
DEC	5.10	.14	9	5.13	.19	8	6.14	.19	8

	30-40S MEAN	30-40S SD	30-40S N	40-50S MEAN	40-50S SD	40-50S N	50-60S MEAN	50-60S SD	50-60S N
JAN	7.25	.30	7	7.56	.34	7	7.11	.42	7
FEB	7.19	.30	7	7.34	.19	7	7.17	.45	7
MAR	7.47	.28	7	7.44	.12	7	7.01	.33	7
APR	8.00	.28	7	7.67	.28	7	7.35	.25	7
MAY	8.36	.47	8	7.82	.26	8	6.98	.17	7
JUN	9.12	.35	8	[illegible].08	.37	8	7.05	.46	7
JUL	9.63	.17	8	6.49	.27	8	6.95	.39	7
AUG	10.01	.29	8	8.68	.12	8	6.72	.38	7
SEP	9.68	.32	8	8.68	.33	8	7.61	.62	8
OCT	9.06	.18	8	8.72	.41	8	7.62	.58	8
NOV	8.42	.29	8	8.15	.28	8	7.30	.51	8
DEC	7.83	.28	8	7.70	.10	8	7.04	.34	8

	60-70S MEAN	60-70S SD	60-70S N	70-80S MEAN	70-80S SD	70-80S N	80-90S MEAN	80-90S SD	80-90S N
JAN	5.78	.28	7	3.70	.15	7	1.24	.03	6
FEB	5.99	.14	7	3.84	.15	7	1.28	.04	6
MAR	5.90	.23	7	3.72	.17	7	1.24	.10	3
APR	5.87	.20	7	3.62	.21	7	1.25	.05	4
MAY	5.67	.28	7	3.45	.09	7	1.16	.14	4
JUN	5.55	.32	7	3.29	.11	7	1.07	.15	6
JUL	5.22	.19	7	3.28	.19	7	1.07	.15	4
AUG	4.99	.21	7	3.10	.27	7	1.08	.19	6
SEP	4.96	.46	8	2.78	.13	8	.98	.17	6
OCT	5.30	.44	8	3.07	.22	8	1.02	.09	7
NOV	5.66	.27	8	3.45	.37	8	1.17	.14	7
DEC	5.79	.30	8	3.64	.17	8	1.25	.03	7

Table 3. Stratospheric mass organized by month and latitude belt. The long-term monthly zonal mean, the interannual standard deviation, and the number of years available are given for each month and latitude. The means and standard deviations must be multiplied by 10^{16} to be expressed in kilograms of stratospheric air.

Station	Latitude	Longitude
Howard AFB	9°N	80°W
Cape Kennedy	29°N	81°W
Buffalo	43°N	79°W
Coral Harbour	64°N	83°W
Eureka	80°N	86°W
Ascension	8°S	14°W
Abidjan	5°N	4°W
Guam	14°N	145°E
Ponape	7°N	158°E
Kwajalein	9°N	168°E
Majuro	7°N	171°E
Yap	10°N	138°E
Koror	7°N	135°E

Table 4. List of radiosonde stations whose tropopause pressures were correlated with the QBO in the 30-millibar zonal wind at Howard AFB.

Table 5a. Zonal mean vertical ozone gradient near the tropopause for each month, for each of 8 Northern Hemisphere latitude belts. The first column is the total number of ozonesonde profiles used. The next 6 columns are the ozone density gradients for variously thick layers below the tropopause, while the remaining 6 columns are the ozone gradients for variously thick layers above the tropopause (see text). Table entries must be multiplied by 10^{-9} to yield units of kg m^{-3} per kilometer. Negative values denote a decrease of ozone with height.

Table 5b. Same as Table 5a except for ozone mass mixing ratio gradients. Entries must be multiplied by 10^{-6} to yield units of g g^{-1} per kilometer.

		N	LAYER BELOW TROPOPAUSE						LAYER ABOVE TROPOPAUSE					
			T-3.0	T-2.5	T-2.0	T-1.5	T-1.0	T-0.5	T+0.5	T+1.0	T+1.5	T+2.0	T+2.5	T+3.0
0-10N														
	JAN	8	.8	.8	.9	1.8	1.8	1.9	8.9	17.9	27.4	34.8	36.3	37.7
	FEB	7	1.3	1.0	.9	.4	-.9	-3.8	7.8	9.2	10.6	18.4	22.0	27.4
	MAR	13	-.7	-.9	-.2	-.4	-1.1	1.0	14.4	20.2	28.7	30.9	34.1	36.0
	APR	12	-2.7	-2.5	-1.5	-1.1	-.1	-.4	15.6	13.2	17.2	19.9	23.4	28.5
	MAY	14	-.2	.1	.4	-1.8	-8.0	2.3	18.7	15.6	18.0	18.5	23.4	30.0
	JUN	15	2.7	3.7	4.8	5.8	9.8	19.4	14.0	23.9	24.4	18.6	20.8	26.7
	JUL	66	1.3	1.8	2.1	2.2	2.4	1.5	8.7	8.5	10.1	13.7	18.1	21.0
	AUG	7	-1.3	-.8	-.3	-.8	.2	-1.4	11.6	8.9	9.6	11.6	13.1	16.1
	SEP	8	-.4	-.8	-1.3	-2.2	-1.9	1.2	20.3	25.2	23.6	23.0	27.8	31.1
	OCT	8	-.2	.3	.2	1.1	3.2	11.0	8.7	11.5	15.4	20.7	26.3	31.0
	NOV	7	-.4	.8	1.4	2.1	-2.0	-13.0	32.8	29.1	27.9	26.3	30.3	32.4
	DEC	7	-.0	-.1	.5	-.0	-.8	-2.8	18.5	28.5	26.6	28.2	31.1	36.0
10-20N														
	JAN	0	-	-	-	-	-	-	-	-	-	-	-	-
	FEB	0	-	-	-	-	-	-	-	-	-	-	-	-
	MAR	2	3.8	4.4	5.3	8.4	8.8	8.8	8.7	9.9	17.9	40.8	50.3	57.1
	APR	1	5.7	8.9	8.8	12.4	19.8	28.7	44.3	20.7	89.5	104.1	94.3	93.5
	MAY	0	-	-	-	-	-	-	-	-	-	-	-	-
	JUN	4	3.6	2.9	1.0	-4.2	-8.6	-10.7	19.1	28.2	27.2	32.1	28.9	37.8
	JUL	1	2.1	2.1	2.1	2.1	2.1	2.1	70.2	65.3	61.5	59.6	58.6	59.0
	AUG	2	-1.8	1.0	5.2	7.6	8.9	10.0	44.0	43.2	42.8	43.3	44.9	49.3
	SEP	2	.4	.2	-.2	-.7	-.9	-.9	24.2	25.6	27.7	28.5	31.3	33.7
	OCT	1	3.7	3.1	2.5	2.4	2.4	2.4	12.7	12.7	12.7	8.0	3.2	1.9
	NOV	1	9.1	8.5	7.6	8.2	5.4	5.4	-14.8	16.0	26.5	16.3	28.2	49.4
	DEC	2	1.0	.9	1.0	1.3	1.8	2.4	32.1	35.9	37.0	40.2	39.9	38.6
20-30N														
	JAN	12	-.7	-.0	1.0	2.9	7.7	10.9	11.8	9.2	9.9	13.3	17.7	21.7
	FEB	15	-.4	-.2	.1	.8	3.6	7.3	20.3	17.2	18.3	18.3	19.5	20.8
	MAR	19	1.2	1.6	1.8	3.0	3.7	2.3	18.0	10.7	14.8	12.8	11.9	12.8
	APR	21	-2.2	-1.7	-1.5	-.4	1.1	4.8	22.7	19.3	9.0	6.8	8.8	7.8
	MAY	23	2.9	3.1	3.6	6.9	12.0	18.0	23.0	13.6	10.2	12.2	12.7	18.1
	JUN	18	2.3	3.9	4.7	7.8	12.9	18.9	50.0	32.1	24.3	29.7	27.5	26.0
	JUL	19	.3	.8	1.1	1.4	2.5	6.5	17.4	24.8	20.1	18.8	18.3	17.1
	AUG	19	-.8	-.8	-1.0	-.3	.8	1.9	20.1	23.4	19.9	15.4	15.0	16.9
	SEP	14	-1.8	-1.3	-.5	.9	1.8	3.3	18.8	17.1	18.2	24.0	23.2	22.3
	OCT	21	-.9	-.3	.7	1.8	3.4	-1.3	19.1	21.4	23.7	25.5	26.6	27.9
	NOV	23	.2	.3	.8	.8	.8	5.7	18.8	18.1	17.2	18.9	17.4	18.1
	DEC	22	-1.3	-1.3	-1.1	-.5	1.0	2.0	14.2	11.3	12.4	16.8	20.9	23.3
30-40N														
	JAN	159	3.1	4.1	5.2	6.7	8.3	12.0	46.2	42.5	35.0	29.5	25.5	21.4
	FEB	126	4.0	5.7	7.7	9.9	13.1	17.2	64.2	58.2	50.5	42.6	36.0	30.5
	MAR	185	1.9	3.1	5.1	7.8	12.2	18.4	77.1	67.6	58.4	48.3	39.3	32.3
	APR	164	4.9	6.9	9.1	12.0	16.1	23.6	87.4	67.1	55.0	44.4	34.5	27.1
	MAY	179	5.7	7.7	10.3	14.4	19.0	23.7	80.6	62.5	48.6	36.1	28.0	22.3
	JUN	142	4.0	5.4	7.2	9.3	13.0	19.2	52.4	43.6	36.8	32.8	30.7	30.5
	JUL	113	1.3	2.3	3.2	4.5	6.4	7.3	35.5	36.2	33.9	33.8	32.3	31.9
	AUG	115	-1.4	-1.1	-.3	1.0	2.7	4.2	22.0	20.1	19.8	21.7	24.3	26.4
	SEP	113	.9	1.1	1.4	1.5	2.2	4.4	18.5	16.8	17.3	20.3	24.4	27.6
	OCT	150	2.6	3.5	4.6	6.1	9.2	14.1	19.0	16.7	15.2	15.7	17.1	19.7
	NOV	140	2.0	3.1	4.4	5.5	6.4	7.5	21.1	16.7	16.4	16.7	17.5	18.2
	DEC	136	1.1	1.9	3.0	3.8	4.8	6.3	28.1	28.4	23.4	20.6	19.0	17.9
40-50N														
	JAN	224	2.3	3.5	5.2	7.7	11.4	18.5	87.7	63.0	58.1	50.5	45.9	41.9
	FEB	205	3.7	5.7	8.5	11.9	15.8	20.4	94.3	91.4	83.0	74.7	65.8	57.7
	MAR	247	3.9	5.8	8.6	12.4	18.1	28.8	116.6	110.8	92.2	77.9	64.8	53.2
	APR	232	6.4	8.4	11.8	16.7	23.8	38.1	130.9	113.0	99.5	84.5	70.6	57.4
	MAY	202	8.0	11.0	15.1	21.0	29.2	40.0	135.5	114.6	92.4	74.5	59.2	45.5
	JUN	161	8.1	10.1	12.4	16.2	21.5	32.0	120.9	94.4	74.3	56.4	42.6	33.0
	JUL	202	3.0	4.5	6.7	9.6	14.0	18.7	81.5	65.8	48.3	36.0	27.1	23.1
	AUG	163	2.0	3.2	4.4	6.7	11.3	15.7	54.6	42.3	30.8	23.5	20.0	17.6
	SEP	177	2.5	3.6	5.3	7.1	9.6	12.3	38.3	30.6	24.5	20.1	18.1	18.3
	OCT	187	1.2	2.0	2.8	4.3	7.5	10.8	29.2	31.4	25.9	21.8	19.3	18.1
	NOV	203	.3	1.1	2.5	4.5	8.4	12.7	45.4	38.5	32.3	27.9	25.4	23.8
	DEC	229	1.8	2.8	4.3	6.8	10.4	18.3	64.4	48.1	42.2	36.9	32.5	29.6
50-60N														
	JAN	196	2.9	4.0	5.7	7.6	10.2	13.4	70.1	65.5	61.1	58.0	54.5	51.2
	FEB	194	1.7	3.0	4.5	6.1	8.0	10.4	94.7	88.8	83.1	77.4	70.1	65.5
	MAR	196	5.2	7.1	10.1	14.2	20.3	27.8	110.6	112.0	103.1	91.1	79.9	69.2
	APR	181	4.8	6.7	9.4	13.0	17.7	26.2	135.6	125.4	113.2	98.7	84.6	69.9
	MAY	180	7.8	9.8	13.0	18.3	26.4	43.6	155.5	129.8	108.9	88.1	68.7	52.0
	JUN	163	8.4	10.7	13.2	17.1	25.2	41.1	163.4	127.2	95.0	68.2	48.8	38.9
	JUL	178	5.9	8.1	11.5	15.7	20.8	27.4	122.5	92.3	66.7	47.4	33.6	25.0
	AUG	249	3.5	4.7	5.8	7.0	9.2	12.2	88.7	69.3	49.4	34.9	25.2	20.1
	SEP	182	2.8	4.2	5.9	8.2	11.6	17.4	81.1	44.0	32.7	27.4	23.1	20.3
	OCT	175	.9	2.0	3.4	5.4	8.0	11.4	52.1	43.6	36.6	31.6	27.7	25.3
	NOV	174	1.1	2.0	3.1	4.5	6.3	8.8	47.6	42.9	36.9	33.1	31.2	28.6
	DEC	175	1.2	2.0	3.0	4.1	6.1	9.1	47.6	44.5	43.3	40.4	37.6	38.0
60-70N														
	JAN	4	3.9	4.5	4.8	4.7	3.9	14.3	100.7	103.4	105.0	100.3	88.0	86.0
	FEB	3	1.9	1.0	3.2	7.3	13.5	43.9	134.0	183.3	135.2	128.3	129.7	129.3
	MAR	6	8.9	8.9	12.5	17.7	28.0	41.7	92.7	87.7	84.3	84.4	85.0	86.8
	APR	9	6.5	7.6	9.9	10.8	28.2	47.6	207.5	172.9	148.9	131.1	121.3	109.2
	MAY	11	12.7	18.3	24.5	37.1	60.1	128.1	146.4	142.8	130.8	109.9	96.2	91.2
	JUN	12	8.2	8.7	13.6	21.2	34.4	86.9	270.3	185.6	147.1	111.1	89.9	65.1
	JUL	19	11.8	15.6	17.3	21.8	24.8	49.4	186.5	161.0	113.8	74.0	64.1	40.7
	AUG	8	10.3	12.4	15.3	13.4	17.6	29.1	109.5	91.3	72.6	82.4	47.7	48.1
	SEP	8	14.8	19.0	22.8	28.4	28.8	2.7	140.4	91.7	45.8	27.0	21.8	22.7
	OCT	5	7.7	10.9	16.0	15.4	21.7	26.3	66.1	61.0	42.3	36.8	29.0	27.6
	NOV	7	1.7	3.3	4.4	5.1	10.5	21.5	74.3	57.0	48.4	42.3	40.0	38.4
	DEC	8	2.2	2.5	2.7	2.2	2.3	6.8	52.3	57.1	88.8	60.8	58.8	53.9
70-80N														
	JAN	61	6.0	6.5	8.5	11.0	14.2	17.2	51.8	48.8	50.0	56.5	60.4	63.5
	FEB	63	6.6	7.3	9.3	11.8	15.4	19.8	76.0	80.0	76.8	76.6	77.1	77.7
	MAR	66	3.8	4.8	5.8	8.0	10.3	13.8	84.8	84.3	86.3	88.1	86.3	82.2
	APR	67	6.0	6.4	8.3	11.1	16.2	19.6	111.9	132.9	139.5	126.1	114.5	102.9
	MAY	65	6.3	7.9	9.7	12.3	16.6	28.3	175.0	159.2	146.9	130.3	111.1	91.8
	JUN	49	6.3	9.1	14.2	22.5	32.0	46.2	200.5	164.1	129.5	97.6	74.3	57.0
	JUL	60	10.5	12.2	14.4	18.5	25.9	50.1	187.7	148.3	106.1	77.3	53.2	37.3
	AUG	60	4.9	6.4	8.6	12.7	19.6	29.9	166.4	127.6	87.8	58.8	41.3	29.3
	SEP	50	3.6	4.9	7.6	11.3	15.9	21.5	87.7	87.4	68.5	49.4	37.1	29.1
	OCT	56	3.7	5.3	7.2	10.0	14.6	19.9	82.4	67.5	56.0	49.7	38.7	30.3
	NOV	47	2.1	3.0	4.2	6.8	6.9	8.7	64.9	59.0	49.7	43.1	39.4	36.4
	DEC	46	.8	1.8	2.9	4.2	8.0	7.6	49.1	57.6	56.8	54.7	53.7	53.4

TABLE 5A.

			LAYER BELOW TROPOPAUSE						LAYER ABOVE TROPOPAUSE					
		N	T-3.0	T-2.5	T-2.0	T-1.5	T-1.0	T-0.5	T+0.5	T+1.0	T+1.5	T+2.0	T+2.5	T+3.0
0-10N														
	JAN	6	.013	.013	.014	.019	.016	.014	.087	.147	.239	.327	.363	.407
	FEB	7	.016	.016	.017	.015	.010	-.004	.062	.073	.087	.137	.204	.268
	MAR	13	.010	.009	.013	.013	.010	.022	.122	.177	.258	.297	.353	.424
	APR	12	.001	.002	.006	.000	.013	.014	.109	.105	.147	.182	.224	.286
	MAY	14	.013	.016	.016	.008	-.018	.029	.128	.125	.133	.171	.226	.301
	JUN	15	.023	.029	.036	.042	.064	.111	.108	.182	.196	.168	.201	.259
	JUL	66	.020	.022	.034	.026	.028	.025	.072	.076	.094	.125	.163	.194
	AUG	7	.003	.005	.007	.007	.009	.003	.066	.056	.063	.060	.097	.127
	SEP	8	.011	.010	.000	.005	.006	.020	.143	.182	.183	.195	.250	.300
	OCT	8	.010	.013	.013	.018	.028	.069	.059	.093	.131	.163	.242	.301
	NOV	7	.008	.013	.017	.020	.004	-.052	.226	.233	.256	.276	.318	.365
	DEC	7	.011	.011	.014	.013	.010	.001	.136	.228	.230	.285	.316	.391
10-20N														
	JAN	0	-	-	-	-	-	-	-	-	-	-	-	-
	FEB	0	-	-	-	-	-	-	-	-	-	-	-	-
	MAR	2	.027	.031	.037	.043	.044	.044	.084	.089	.151	.344	.444	.530
	APR	1	.048	.056	.069	.093	.143	.203	.358	.223	.834	1.006	.995	1.076
	MAY	0	-	-	-	-	-	-	-	-	-	-	-	-
	JUN	4	.023	.022	.016	-.000	-.016	-.024	.120	.184	.162	.197	.204	.298
	JUL	1	.021	.022	.023	.023	.023	.023	.429	.479	.519	.539	.550	.578
	AUG	2	.019	.029	.045	.054	.060	.065	.302	.348	.367	.382	.408	.464
	SEP	2	.007	.007	.006	.004	.004	.004	.143	.171	.211	.244	.281	.310
	OCT	1	.023	.023	.023	.023	.023	.023	.088	.088	.088	.070	.042	.038
	NOV	1	.043	.042	.041	.040	.039	.039	-.050	.121	.179	.128	.226	.403
	DEC	2	.026	.027	.027	.029	.032	.036	.275	.323	.337	.361	.369	.385
20-30N														
	JAN	12	.011	.013	.018	.026	.044	.059	.087	.084	.098	.131	.173	.219
	FEB	15	.010	.011	.012	.014	.025	.037	.112	.118	.142	.167	.200	.230
	MAR	19	.019	.021	.023	.026	.028	.022	.082	.079	.119	.123	.129	.149
	APR	21	.010	.011	.013	.016	.020	.029	.111	.105	.077	.078	.085	.104
	MAY	23	.030	.032	.035	.047	.069	.085	.142	.110	.099	.118	.130	.159
	JUN	18	.026	.033	.038	.052	.074	.099	.281	.212	.185	.240	.246	.260
	JUL	19	.023	.026	.028	.030	.035	.047	.115	.164	.153	.146	.164	.168
	AUG	19	.015	.016	.016	.019	.023	.026	.116	.147	.144	.130	.139	.162
	SEP	14	.008	.009	.012	.017	.020	.027	.094	.107	.125	.173	.183	.190
	OCT	21	.009	.011	.015	.020	.027	.005	.114	.139	.168	.195	.222	.252
	NOV	23	.013	.014	.016	.018	.019	.042	.108	.115	.123	.136	.154	.181
	DEC	22	.007	.008	.009	.011	.016	.018	.081	.068	.088	.135	.178	.211
30-40N														
	JAN	159	.019	.022	.025	.030	.035	.045	.181	.158	.145	.136	.131	.125
	FEB	126	.022	.026	.032	.038	.047	.057	.211	.206	.191	.179	.169	.161
	MAR	185	.018	.022	.027	.035	.047	.067	.245	.236	.222	.204	.187	.176
	APR	154	.028	.034	.041	.049	.061	.084	.300	.258	.233	.207	.184	.169
	MAY	179	.034	.040	.049	.061	.075	.089	.307	.266	.236	.203	.186	.177
	JUN	142	.032	.037	.044	.052	.065	.086	.241	.222	.215	.218	.226	.246
	JUL	113	.025	.029	.033	.039	.047	.054	.202	.223	.230	.252	.266	.288
	AUG	115	.018	.020	.023	.029	.036	.042	.138	.143	.154	.177	.207	.237
	SEP	113	.020	.021	.023	.024	.027	.036	.121	.125	.140	.172	.214	.252
	OCT	150	.024	.028	.032	.039	.051	.070	.107	.106	.110	.123	.146	.177
	NOV	140	.021	.025	.029	.033	.037	.041	.111	.100	.111	.122	.138	.155
	DEC	136	.016	.019	.022	.025	.029	.033	.114	.116	.115	.115	.120	.127
40-50N														
	JAN	224	.015	.018	.022	.029	.038	.056	.203	.204	.186	.195	.192	.190
	FEB	205	.020	.025	.032	.041	.052	.064	.286	.296	.291	.283	.270	.259
	MAR	247	.022	.027	.034	.044	.059	.086	.357	.360	.323	.296	.270	.248
	APR	232	.030	.035	.044	.057	.075	.105	.392	.367	.349	.324	.299	.27[illegible]
	MAY	202	.036	.044	.056	.072	.096	.128	.436	.403	.359	.322	.288	.254
	JUN	161	.038	.044	.051	.063	.079	.108	.413	.354	.315	.275	.242	.220
	JUL	202	.027	.032	.039	.048	.062	.078	.305	.277	.236	.203	.189	.189
	AUG	163	.021	.025	.029	.036	.049	.062	.207	.183	.156	.141	.139	.140
	SEP	177	.021	.026	.030	.036	.044	.053	.160	.143	.132	.126	.130	.144
	OCT	187	.014	.016	.019	.024	.033	.043	.140	.126	.117	.112	.111	.115
	NOV	203	.011	.013	.017	.022	.032	.043	.145	.134	.125	.120	.122	.126
	DEC	229	.014	.017	.020	.028	.035	.047	.169	.162	.154	.149	.145	.145
50-60N														
	JAN	196	.017	.020	.024	.028	.034	.041	.205	.205	.206	.210	.212	.215
	FEB	194	.015	.018	.021	.025	.030	.036	.276	.275	.275	.273	.267	.269
	MAR	196	.025	.030	.037	.047	.061	.079	.320	.339	.331	.315	.299	.287
	APR	181	.026	.031	.038	.047	.058	.078	.387	.382	.371	.353	.330	.300
	MAY	180	.035	.040	.049	.062	.082	.122	.457	.419	.387	.347	.303	.262
	JUN	163	.036	.043	.050	.061	.083	.123	.500	.427	.358	.294	.247	.216
	JUL	178	.031	.037	.046	.058	.073	.093	.402	.332	.270	.223	.190	.170
	AUG	249	.023	.026	.030	.034	.041	.050	.282	.249	.201	.166	.143	.135
	SEP	162	.020	.024	.029	.035	.044	.058	.203	.167	.143	.136	.131	.130
	OCT	175	.014	.016	.020	.025	.031	.040	.165	.151	.142	.138	.136	.138
	NOV	174	.013	.015	.018	.021	.026	.031	.143	.139	.132	.132	.137	.139
	DEC	175	.013	.015	.018	.020	.025	.032	.144	.144	.150	.150	.152	.158
60-70N														
	JAN	4	.019	.021	.023	.024	.023	.047	.280	.314	.339	.343	.315	.275
	FEB	3	.013	.012	.017	.025	.039	.102	.322	.398	.388	.407	.443	.473
	MAR	6	.023	.028	.035	.047	.063	.101	.261	.268	.272	.282	.303	.330
	APR	9	.023	.026	.031	.035	.068	.118	.567	.488	.439	.423	.428	.422
	MAY	11	.043	.057	.074	.108	.174	.363	.408	.437	.442	.406	.398	.427
	JUN	12	.024	.030	.041	.059	.091	.174	.778	.580	.488	.408	.367	.308
	JUL	19	.040	.045	.055	.066	.076	.135	.545	.515	.409	.311	.266	.235
	AUG	6	.036	.042	.050	.050	.064	.095	.350	.312	.270	.264	.230	.240
	SEP	8	.045	.057	.068	.084	.088	.030	.423	.322	.207	.159	.148	.160
	OCT	5	.026	.033	.042	.045	.061	.074	.180	.191	.153	.146	.133	.138
	NOV	7	.018	.020	.023	.025	.038	.063	.230	.200	.186	.178	.186	.198
	DEC	9	.015	.018	.017	.017	.019	.029	.143	.166	.198	.197	.196	.203
70-80N														
	JAN	51	.021	.025	.029	.035	.042	.047	.140	.137	.157	.183	.204	.226
	FEB	63	.021	.025	.029	.035	.043	.053	.196	.214	.221	.232	.249	.266
	MAR	66	.025	.025	.026	.032	.035	.039	.251	.259	.278	.297	.299	.306
	APR	67	.021	.024	.028	.034	.042	.081	.257	.325	.354	.353	.345	.335
	MAY	65	.024	.028	.032	.038	.047	.072	.422	.413	.409	.394	.366	.333
	JUN	49	.029	.035	.046	.063	.085	.118	.527	.476	.404	.349	.298	.262
	JUL	80	.030	.041	.047	.057	.075	.132	.518	.453	.370	.301	.244	.208
	AUG	60	.024	.028	.033	.044	.061	.086	.480	.390	.303	.241	.199	.171
	SEP	50	.019	.022	.028	.036	.046	.089	.268	.257	.222	.182	.159	.147
	OCT	56	.018	.021	.025	.032	.042	.054	.217	.198	.179	.159	.148	.141
	NOV	47	.015	.016	.019	.022	.025	.030	.163	.157	.144	.138	.141	.143
	DEC	46	.012	.014	.016	.019	.024	.027	.128	.157	.165	.172	.183	.185

TABLE 5B.

Tables 6a - 6h. Frequency distributions of vertical ozone gradient above the tropopause by month and thickness of layer above tropopause for each of eight latitude belts from 0^{o}-80^{o}N. Table entries are percentage of N, given at right, falling in each gradient category shown at top. Categories are in units of 10^{-9} kg m^{-3} per kilometer (see text).

Tables 7a - 7h. Same as Tables 6a - 6h except for below tropopause.

		0-10N																
MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5	33	33		17		17											6
JAN	1.0	17	33		17	33												6
JAN	1.5		33		17		33	17										6
JAN	2.0	17	17			17	17	33										6
JAN	2.5	17	17				33	33										6
JAN	3.0		33				17	50										6
FEB	.5	29	29	29	14													7
FEB	1.0		57	43														7
FEB	1.5		71	14		14												7
FEB	2.0		57	14	14		14											7
FEB	2.5		43		43			14										7
FEB	3.0		14	29	29		14	14										7
MAR	.5	15	31	15	23	15												13
MAR	1.0	8	31	15	8	31	8											13
MAR	1.5		8	15	38	23		15										13
MAR	2.0		8	8	23	46	15											13
MAR	2.5		8	8	8	46	31											13
MAR	3.0			23		8	62	8										13
APR	.5		33	33	25		8											12
APR	1.0	25	17	33	17			8										12
APR	1.5		50	25	8	8		8										12
APR	2.0	8	42	17	17	8		8										12
APR	2.5		42	8	17	17	8	8										12
APR	3.0		17	25	17	25		17										12
MAY	.5	21	21	29		7	7	14										14
MAY	1.0	14	29	14	29	14												14
MAY	1.5	7	29	36	7	14	7											14
MAY	2.0	7	29	29	14	7	7	7										14
MAY	2.5		14	50	14	7		14										14
MAY	3.0		14	14	29	29		14										14
JUN	.5	27	20	13	20	7	7	7										15
JUN	1.0	20	13	40		7	13			7								15
JUN	1.5	13	33	20	13	7		7	7									15
JUN	2.0		60	13	7	7		13										15
JUN	2.5		53	13	13		7	13										15
JUN	3.0		27	27	20		13	13										15
JUL	.5	24	32	21	17	3	2	2										66
JUL	1.0	32	21	26	18	3												66
JUL	1.5	23	27	32	14	3		2										66
JUL	2.0	11	35	24	20	8	3											66
JUL	2.5	2	21	36	26	14	2											66
JUL	3.0		12	30	44	12	2											66
AUG	.5	29	14	29	14	14												7
AUG	1.0		57	43														7
AUG	1.5		57	43														7
AUG	2.0	14		86														7
AUG	2.5		29	57	14													7
AUG	3.0		29	43	14	14												7
SEP	.5	13	13	38	25			13										8
SEP	1.0		13	50		13	13	13										8
SEP	1.5		25	25	13	25	13											8
SEP	2.0		13	25	38	13	13											8
SEP	2.5		25		25	13	38											8
SEP	3.0		25		13	25	25	13										8
OCT	.5	25	38	25		13												8
OCT	1.0	13	50	25		13												8
OCT	1.5	13	13	50	13		13											8
OCT	2.0		38	25		25		13										8
OCT	2.5		25	13	25	13	13	13										8
OCT	3.0			38		38	13	13										8
NOV	.5			57		14	14	14										7
NOV	1.0		29	29	14	14		14										7
NOV	1.5	14	43				14	29										7
NOV	2.0	14	14	14	14		14	29										7
NOV	2.5	14	14		14	14	29	14										7
NOV	3.0	14	14			29	29	14										7
DEC	.5		14	43	43													7
DEC	1.0		29	43				29										7
DEC	1.5		14	29	29		14	14										7
DEC	2.0		14		57		14	14										7
DEC	2.5		14	14	29	14	14	14										7
DEC	3.0			14	14	43		29										7

Table 6a.

10-20N

MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5																	0
JAN	1.0																	0
JAN	1.5																	0
JAN	2.0																	0
JAN	2.5																	0
JAN	3.0																	0
FEB	.5																	0
FEB	1.0																	0
FEB	1.5																	0
FEB	2.0																	0
FEB	2.5																	0
FEB	3.0																	0
MAR	.5		50	50														2
MAR	1.0		50	50														2
MAR	1.5		50			50												2
MAR	2.0				50			50										2
MAR	2.5					50		50										2
MAR	3.0							100										2
APR	.5						100											1
APR	1.0				100													1
APR	1.5							100										1
APR	2.0								100									1
APR	2.5							100										1
APR	3.0							100										1
MAY	.5																	0
MAY	1.0																	0
MAY	1.5																	0
MAY	2.0																	0
MAY	2.5																	0
MAY	3.0																	0
JUN	.5		25	25		50												4
JUN	1.0		25			75												4
JUN	1.5			25	25	25	25											4
JUN	2.0		25	25	25			25										4
JUN	2.5			75				25										4
JUN	3.0			25	25	25		25										4
JUL	.5							100										1
JUL	1.0							100										1
JUL	1.5							100										1
JUL	2.0							100										1
JUL	2.5							100										1
JUL	3.0							100										1
AUG	.5				50			50										2
AUG	1.0				50			50										2
AUG	1.5				50			50										2
AUG	2.0				50			50										2
AUG	2.5					50		50										2
AUG	3.0					50		50										2
SEP	.5		50				50											2
SEP	1.0			50		50												2
SEP	1.5			50		50												2
SEP	2.0			50		50												2
SEP	2.5				50	50												2
SEP	3.0				50		50											2
OCT	.5			100														1
OCT	1.0			100														1
OCT	1.5			100														1
OCT	2.0		100															1
OCT	2.5		100															1
OCT	3.0		100															1
NOV	.5	100																1
NOV	1.0			100														1
NOV	1.5				100													1
NOV	2.0			100														1
NOV	2.5				100													1
NOV	3.0						100											1
DEC	.5			50				50										2
DEC	1.0			50				50										2
DEC	1.5			50				50										2
DEC	2.0			50				50										2
DEC	2.5			50				50										2
DEC	3.0			50				50										2

Table 6b.

20-30N

MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5	25	25	25	8		17											12
JAN	1.0	33	33	17			8	8										12
JAN	1.5	42	25	17		8		8										12
JAN	2.0	42	33			8		17										12
JAN	2.5	17	58				8	17										12
JAN	3.0	25	42	8				25										12
FEB	.5	13	7	33	20	13	7	7										15
FEB	1.0	20	13	33	13	7	7	7										15
FEB	1.5	13	40	27		7	7		7									15
FEB	2.0	13	40	33				7	7									15
FEB	2.5	33	27	20	7			7	7									15
FEB	3.0	33	20	27				13	7									15
MAR	.5	16	47	16	5	11			5									19
MAR	1.0	21	32	11	26	5		5										19
MAR	1.5	32	37	11	5			16										19
MAR	2.0	37	32	11	5			16										19
MAR	2.5	42	26	16				16										19
MAR	3.0	47	21	11	5			11	5									19
APR	.5	14	33	10	14	10	5	10	5									21
APR	1.0	19	38	19		5		14	5									21
APR	1.5	38	38	10			10	5										21
APR	2.0	38	43	5	5		5	5										21
APR	2.5	38	43	5	5		5	5										21
APR	3.0	38	33	14			10	5										21
MAY	.5	13	26	13	13	4	17	9	4									23
MAY	1.0	17	35	13	17		9	9										23
MAY	1.5	17	39	17	9	9	4	4										23
MAY	2.0	26	30	17	4	9	9	4										23
MAY	2.5	30	22	22	13		4	9										23
MAY	3.0	22	30	17	13	4	9	4										23
JUN	.5	17	11	17		6	6	28	11		6							18
JUN	1.0	22	11	17	11	6	11	11	11									18
JUN	1.5	22		28	17		11	22										18
JUN	2.0	17	11	11	22	6	11	22										18
JUN	2.5	22	22		22	6	6	22										18
JUN	3.0	17	11	11	17	17	11	17										18
JUL	.5	26	21	5	16	11	11	5		5								19
JUL	1.0	16	16	11	11	21		26										19
JUL	1.5	21	26	16		16		21										19
JUL	2.0	37	16	5	11	11		21										19
JUL	2.5	37	16		16	5	16	11										19
JUL	3.0	26	21	5	11	26	11											19
AUG	.5	16	26	16	11	5	16	11										19
AUG	1.0	11	26	32	11			16	5									19
AUG	1.5	32	16	21	5	5		21										19
AUG	2.0	26	32	11	5	11	5	11										19
AUG	2.5	21	32	11	11	21	5											19
AUG	3.0	16	16	32	11	21	5											19
SEP	.5		57	21	7	7		7										14
SEP	1.0	14	29	29	14		7	7										14
SEP	1.5	7	36	14	14	21	7											14
SEP	2.0		50	7		14	14	14										14
SEP	2.5		43	14		21	7	14										14
SEP	3.0		43	14	7	14	7	14										14
OCT	.5		29	19	43		10											21
OCT	1.0	5	29	24	19	19			5									21
OCT	1.5	5	19	19	24	19	5	10										21
OCT	2.0	5	24	14	19	14	14	10										21
OCT	2.5	5	14	24	10	19	10	19										21
OCT	3.0	5	14	19	14	19	10	19										21
NOV	.5	13	22	26	17	9	9	4										23
NOV	1.0	13	39	17	13		9	9										23
NOV	1.5	9	43	17	9	13		9										23
NOV	2.0	9	43	13	22	4		9										23
NOV	2.5	17	26	22	22		4	9										23
NOV	3.0	4	48	13	9	4	9	13										23
DEC	.5	9	27	27	32		5											22
DEC	1.0	14	45	23	14		5											22
DEC	1.5	14	50	18		14		5										22
DEC	2.0	14	41	23	9	5		5	5									22
DEC	2.5	14	41	14	9	9	5	5	5									22
DEC	3.0	9	45		14	5	14	9	5									22

Table 6c.

30-40N

MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5	9	11	13	9	8	11	28	11	1	1							159
JAN	1.0	11	14	14	9	7	8	28	8	1		1						159
JAN	1.5	11	18	12	12	12	6	22	6	1								159
JAN	2.0	14	19	13	9	14	8	18	4									159
JAN	2.5	21	18	9	12	11	13	11	4									159
JAN	3.0	25	18	12	13	12	7	11	3									159
FEB	.5	7	13	6	8	8	9	30	13	4	2			1	1			126
FEB	1.0	8	12	10	8	6	9	29	11	6	2							126
FEB	1.5	11	13	7	10	8	6	26	15	3								126
FEB	2.0	18	10	5	9	10	6	32	10									126
FEB	2.5	21	11	7	11	9	5	31	5									126
FEB	3.0	25	14	6	11	10	5	25	5									126
MAR	.5	6	10	9	5	9	4	29	14	7	5	2		1				185
MAR	1.0	7	11	11	8	6	7	24	16	8	1	2						185
MAR	1.5	11	11	11	6	8	5	24	17	5	2							185
MAR	2.0	12	11	9	10	8	4	32	11	3								185
MAR	2.5	17	14	9	8	10	5	30	7	1								185
MAR	3.0	21	17	9	9	6	4	29	4									185
APR	.5	10	7	9	3	6	4	28	12	12	3	1	2		1		1	184
APR	1.0	18	6	8	4	5	5	27	18	6	1	1	1	1				184
APR	1.5	16	10	9	3	6	3	31	16	4	1							184
APR	2.0	22	8	8	9	6	6	24	14	4								153
APR	2.5	26	10	10	7	7	7	24	8	1								153
APR	3.0	29	12	9	8	9	6	20	6	1								153
MAY	.5	9	10	7	6	5	5	27	16	6	4	3	2	1	1			179
MAY	1.0	11	9	9	6	9	5	24	18	4	3	1	1					179
MAY	1.5	13	9	13	9	5	4	31	13	3								179
MAY	2.0	18	7	12	9	10	6	32	4	1								179
MAY	2.5	20	15	12	9	9	11	24	1									179
MAY	3.0	20	16	13	14	11	8	18	1									179
JUN	.5	10	10	9	10	8	10	23	13	4	1	1						142
JUN	1.0	10	11	13	11	8	8	31	6	2								142
JUN	1.5	11	8	23	7	10	10	27	4									142
JUN	2.0	13	13	13	12	12	7	27	4									142
JUN	2.5	11	18	13	8	14	11	23	2									141
JUN	3.0	13	14	10	13	12	16	20	1									141
JUL	.5	19	13	15	4	13	4	25	4	2			1					113
JUL	1.0	12	14	15	15	8	4	28	4			1						113
JUL	1.5	11	16	16	13	11	5	25	3	1								113
JUL	2.0	14	12	16	6	12	12	27	2									113
JUL	2.5	12	14	13	6	13	10	31	1									113
JUL	3.0	11	12	10	13	12	16	27										113
AUG	.5	23	14	23	8	10	6	15					1					115
AUG	1.0	25	12	23	11	10	7	9	3									115
AUG	1.5	23	17	15	18	8	8	11										115
AUG	2.0	15	17	17	17	14	11	9										115
AUG	2.5	10	14	17	20	15	13	11										115
AUG	3.0	7	12	24	13	17	13	13										115
SEP	.5	17	27	22	11	12	2	8	1									113
SEP	1.0	18	22	25	16	7	3	9	1									113
SEP	1.5	13	22	27	19	10	5	4										113
SEP	2.0	12	25	18	19	12	6	8										113
SEP	2.5	11	19	23	15	9	9	12	2									113
SEP	3.0	10	15	21	16	12	10	17	1									112
OCT	.5	15	23	21	13	9	5	13	1	1								150
OCT	1.0	14	26	17	17	12	3	11										150
OCT	1.5	12	28	22	17	7	9	5										150
OCT	2.0	13	26	24	15	11	7	5										150
OCT	2.5	13	23	23	16	11	7	7										150
OCT	3.0	14	21	19	16	11	10	9										150
NOV	.5	16	20	21	16	11	4	11	1									140
NOV	1.0	19	21	24	14	9	4	9										140
NOV	1.5	20	21	24	13	11	4	7	1									140
NOV	2.0	19	21	27	14	6	5	8	1									140
NOV	2.5	16	24	21	18	9	6	5	1									140
NOV	3.0	18	22	17	19	12	5	7										140
DEC	.5	10	17	18	18	15	7	10	4	1								136
DEC	1.0	10	19	18	20	14	3	13	4									136
DEC	1.5	12	21	18	15	18	5	9	2									136
DEC	2.0	10	30	18	15	13	4	8	1									136
DEC	2.5	11	30	24	13	9	6	6	1									136
DEC	3.0	12	32	22	15	7	2	9	1									136

Table 6d.

40-50N

MONTH	LAYER	<0	10	20	30	40	60	100	150	200	250	300	350	400	450	500	≥600	N
JAN	.5	7	3	4	8	8	8	39	16	7								224
JAN	1.0	4	5	4	8	7	9	44	16	2								224
JAN	1.5	3	8	4	10	8	10	45	11									224
JAN	2.0	6	5	7	11	8	11	44	8									224
JAN	2.5	8	4	12	9	10	15	36	6									224
JAN	3.0	8	6	9	11	16	11	35	3									224
FEB	.5	4	1	2	6	5	8	35	22	10	4		1					205
FEB	1.0	3	2	1	4	8	6	37	24	9	4							205
FEB	1.5	3	2	3	4	5	7	40	28	4	1	1						205
FEB	2.0	4	2	4	4	7	5	46	21	3	1	1						205
FEB	2.5	5	4	4	6	7	9	43	18	3								205
FEB	3.0	8	3	6	5	9	12	46	9	1								205
MAR	.5	5	3	2	3	2	2	31	23	15	6	4	2	2				247
MAR	1.0	3	2	2	3	4	5	26	30	16	5	2	1					247
MAR	1.5	5	1	3	6	3	6	31	30	11	2							247
MAR	2.0	7	1	2	8	8	6	36	28	6	1							247
MAR	2.5	8	3	5	6	4	8	44	19	2								247
MAR	3.0	9	6	5	9	8	10	41	11	1								247
APR	.5	4	3	2	2	3	5	28	19	15	9	7	2	1			1	232
APR	1.0	3	2	1	3	2	4	31	27	16	7	1			1			232
APR	1.5	3	2	3	3	3	8	32	32	9	5	1						232
APR	2.0	4	5	4	2	8	4	38	30	6	2							232
APR	2.5	7	4	3	3	8	8	44	20	3	1							232
APR	3.0	9	4	6	8	8	10	44	11	2								232
MAY	.5	4	2	3	2	2	3	28	22	14	6	4	2	2	2	1	1	202
MAY	1.0	3	2	3	1	4	5	22	30	19	3	4	1					202
MAY	1.5	5	3	2	3	3	4	33	32	8	4							202
MAY	2.0	8	2	2	6	5	4	43	22	8	1							202
MAY	2.5	9	4	3	5	11	9	43	13	2								202
MAY	3.0	10	6	10	8	11	12	34	8	1								202
JUN	.5	5	3	4	7	1	5	25	21	14	7	1	1	1	1	1	2	161
JUN	1.0	6	2	5	6	2	8	30	26	11	3	1		1				161
JUN	1.5	8	4	4	5	8	9	39	16	9	1							161
JUN	2.0	7	7	7	6	9	9	40	12	2								161
JUN	2.5	10	9	9	5	13	12	35	6									161
JUN	3.0	15	8	11	11	12	13	29	2									161
JUL	.5	13	4	8	5	5	6	23	18	8	2	2	1					202
JUL	1.0	13	6	7	8	3	6	29	18	7	1							202
JUL	1.5	15	7	10	6	9	8	31	12	1								202
JUL	2.0	16	14	8	6	11	8	34	3									202
JUL	2.5	19	12	9	13	11	12	22										202
JUL	3.0	18	14	14	13	12	11	17										202
AUG	.5	12	8	11	8	9	7	25	13	4	2		1					163
AUG	1.0	14	12	13	7	12	4	26	7	5								163
AUG	1.5	15	13	17	10	9	8	21	6									163
AUG	2.0	19	17	18	13	10	7	17										163
AUG	2.5	17	15	23	16	15	5	9										163
AUG	3.0	17	17	25	17	13	6	5										163
SEP	.5	16	12	10	9	11	11	22	7	2								177
SEP	1.0	18	15	12	9	10	10	22	4									177
SEP	1.5	17	15	16	12	11	12	16	1									177
SEP	2.0	17	18	19	19	12	6	10										177
SEP	2.5	14	19	29	17	7	6	7										177
SEP	3.0	13	22	23	20	11	5	6	1									177
OCT	.5	11	16	11	12	11	9	21	7	1		1						187
OCT	1.0	13	15	13	16	9	9	22	2	1								187
OCT	1.5	14	16	15	14	16	7	18										187
OCT	2.0	15	18	18	17	11	10	12										187
OCT	2.5	18	19	22	14	13	7	8										187
OCT	3.0	17	19	24	14	11	11	4										187
NOV	.5	5	10	10	14	15	12	25	8	2								203
NOV	1.0	7	12	13	12	12	12	28	4									203
NOV	1.5	9	13	13	15	17	11	19	3									203
NOV	2.0	8	17	15	21	13	13	14										203
NOV	2.5	12	18	17	19	14	10	12										203
NOV	3.0	10	15	21	18	18	7	12										203
DEC	.5	6	6	9	9	15	8	32	11	4								229
DEC	1.0	6	9	9	12	12	10	34	7	2								229
DEC	1.5	5	6	15	12	13	12	30	4									229
DEC	2.0	7	9	15	18	10	16	23	3									229
DEC	2.5	8	12	15	14	15	11	22	1									229
DEC	3.0	10	14	18	10	15	15	17	1									229

Table 6e.

60-80N

MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5	5	7	5	8	10	7	34	16	7	2		1					196
JAN	1.0	6	5	4	9	10	6	39	15	5	1							196
JAN	1.5	4	6	5	9	12	7	43	11	3	1							196
JAN	2.0	4	5	4	9	12	8	45	11	1	1							196
JAN	2.5	5	3	7	6	15	12	41	10	1	1							196
JAN	3.0	5	4	6	10	12	16	40	6	1								196
FEB	.5	7	6	4	5	7	3	29	17	13	8	2	1	1				194
FEB	1.0	7	5	4	4	5	4	29	25	13	3	1			1			194
FEB	1.5	5	4	3	5	5	5	39	25	7	1	1						194
FEB	2.0	6		4	4	8	6	42	26	3	2							194
FEB	2.5	5	2	2	5	7	6	51	19	3		1						194
FEB	3.0	6	1	4	4	7	9	55	12	2	1							194
MAR	.5	7	3	3	7	5	3	23	19	14	12	2	2		1	1		196
MAR	1.0	4	4	2	5	4	4	26	25	14	8	3	2					196
MAR	1.5	4	3	4	2	3	7	25	28	19	4	1	1					196
MAR	2.0	5	2	2	3	5	7	34	32	10	2							196
MAR	2.5	7	2	4	4	5	4	42	26	6								196
MAR	3.0	9	2	6	5	3	7	44	23	2								196
APR	.5	4	2	1	4	2	3	24	24	15	7	5	3	3	1	1	1	181
APR	1.0	3	2	1	3	3	4	24	25	24	7	3	1	1		1		181
APR	1.5	2	2	2	1	2	2	30	33	19	5	1	1					181
APR	2.0	3	1	1	1	4	5	37	35	12	2							181
APR	2.5	3		1	4	5	8	45	27	7								181
APR	3.0	4	3	3	6	6	7	47	22	2								181
MAY	.5	2	1	2	2	1	4	19	22	21	11	9	3	1	2	1		180
MAY	1.0	2		1	1	2	4	22	29	22	13	3						180
MAY	1.5	2	2	1	2	2	6	25	40	17	3	1						180
MAY	2.0	3	2	3	4	3	3	42	34	6								180
MAY	2.5	7	3	4	1	4	8	57	17	1								180
MAY	3.0	8	4	3	9	11	6	51	6									180
JUN	.5	2	1	1	3	2	2	21	21	13	13	9	6	3	1	1	1	163
JUN	1.0	2	1	1	2	3	4	20	29	26	12	1	1					163
JUN	1.5	4	4	1	1	2	7	36	34	10	2							163
JUN	2.0	6	3	4	4	7	4	53	16	2								163
JUN	2.5	7	6	6	7	6	13	47	7									163
JUN	3.0	10	7	9	14	17	13	27	2									163
JUL	.5	7	4	5	2	7	3	15	20	13	11	6	3	2	2			178
JUL	1.0	8	5	2	3	3	7	24	26	16	5	1						178
JUL	1.5	6	6	4	5	9	8	40	16	4								178
JUL	2.0	7	7	10	8	10	9	42	7									178
JUL	2.5	10	9	12	16	17	12	22	2									178
JUL	3.0	16	12	14	19	12	11	17										178
AUG	.5	8	6	8	5	6	3	28	17	9	4	4		1				249
AUG	1.0	7	5	7	5	8	8	35	20	5	2							249
AUG	1.5	6	8	8	6	14	11	38	7	1								249
AUG	2.0	10	8	11	14	13	15	28	1									249
AUG	2.5	11	13	16	16	14	16	10										249
AUG	3.0	13	14	22	19	16	7	6										249
SEP	.5	10	12	9	9	7	5	25	14	6	2	1						162
SEP	1.0	8	14	13	7	10	5	32	11									162
SEP	1.5	9	19	12	10	13	10	26	2									162
SEP	2.0	11	13	20	14	10	10	21	1									162
SEP	2.5	10	13	23	19	13	14	7										162
SEP	3.0	11	18	19	24	18	5	6										162
OCT	.5	6	5	15	10	8	11	32	8	3	1	1						175
OCT	1.0	5	9	15	12	9	12	31	8	1								175
OCT	1.5	7	8	17	14	12	11	29	2									175
OCT	2.0	6	11	17	13	17	14	19	2									175
OCT	2.5	7	10	22	15	19	14	10	2									175
OCT	3.0	7	13	21	22	21	8	9	1									175
NOV	.5	8	11	12	9	11	10	30	9	1	1							174
NOV	1.0	5	12	11	10	15	10	29	7									174
NOV	1.5	6	10	14	14	16	11	27	2									174
NOV	2.0	6	11	14	17	12	13	24	1									174
NOV	2.5	7	10	17	18	15	11	21	1									174
NOV	3.0	8	13	16	16	17	13	15	1									174
DEC	.5	5	9	9	14	9	11	36	5	2	1							175
DEC	1.0	8	8	5	15	15	15	34	3	1	1							175
DEC	1.5	7	6	7	13	14	17	31	3	1								175
DEC	2.0	7	5	11	11	16	11	34	1	1								175
DEC	2.5	6	6	12	13	16	10	31	1									175
DEC	3.0	7	9	11	17	15	13	27	2									175

Table 6f.

								60-70N										
MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5				25				50	25								4
JAN	1.0				25				75									4
JAN	1.5							25	75									4
JAN	2.0							50	50									4
JAN	2.5				25			25	50									4
JAN	3.0	25						75										4
FEB	.5							33	33		33							3
FEB	1.0								33	67								3
FEB	1.5								67	33								3
FEB	2.0								100									3
FEB	2.5								100									3
FEB	3.0								100									3
MAR	.5	13						50	13	25								8
MAR	1.0	13						50	13	25								8
MAR	1.5				13	13		50	13	13								8
MAR	2.0						13	75			13							8
MAR	2.5			13			13	38	25		13							8
MAR	3.0		13				38	13	25		13							8
APR	.5						11		44	11				22	11			9
APR	1.0								44	22	22		11					9
APR	1.5							11	44	44								9
APR	2.0							22	44	22	11							9
APR	2.5							33	33	33								9
APR	3.0							44	22	33								9
MAY	.5	9		9					9	9	36		9		9		9	11
MAY	1.0	9		9				9	27		9	27		9				11
MAY	1.5	9				9		27		27	18	9						11
MAY	2.0	9					9	27	18	36								11
MAY	2.5	9				9		27	36	18								11
MAY	3.0				9		9	27	55									11
JUN	.5						8		8	17	8	25	8	8		8	8	12
JUN	1.0						8	17	8	25	8	17	17					12
JUN	1.5	8	8					17	17	17	17	8	8					12
JUN	2.0				8		17	17	33	17	8							12
JUN	2.5			8	8			42	33	8								12
JUN	3.0			17	8			67		8								12
JUL	.5							5	42	16	16	5	5	11				19
JUL	1.0							32	32	5	16	11				5		19
JUL	1.5							63	16	11	5	5						19
JUL	2.0					16	11	53	16	5								19
JUL	2.5			5	5	11	37	37	5									19
JUL	3.0	5	5		16	37	11	26										19
AUG	.5			13			13	25	38			13						8
AUG	1.0	13				13		38	25		13							8
AUG	1.5	13					13	63	13									8
AUG	2.0					13	38	50										8
AUG	2.5				25	25		38	13									8
AUG	3.0				38	25	13	13	13									8
SEP	.5					13	13	13	38		13		13					8
SEP	1.0	13						63	13			13						8
SEP	1.5	13			13	25	13	25	13									8
SEP	2.0	38		13	13		13	13	13									8
SEP	2.5	25	25	13	13			25										8
SEP	3.0	13	38	13	13		13	13										8
OCT	.5			20		20	40			20								5
OCT	1.0			60		20					20							5
OCT	1.5			60		20			20									5
OCT	2.0		20	20	20	20		20										5
OCT	2.5			40	20	20		20										5
OCT	3.0		20	20	20		20	20										5
NOV	.5	29				14		14	29	14								7
NOV	1.0	14	14			14		29	29									7
NOV	1.5	14		14		14		57										7
NOV	2.0		14		14	14	14	43										7
NOV	2.5		14		14	29	29	14										7
NOV	3.0		14	14	14	29		29										7
DEC	.5				22	11	22	44										9
DEC	1.0					33	22	13	11									9
DEC	1.5					22	22	33	22									9
DEC	2.0					11	33	33	22									9
DEC	2.5					22	44	33										9
DEC	3.0				11	22	22	44										9

Table 6g.

70-80N

MONTH	LAYER	<0	10	20	30	40	50	100	150	200	250	300	350	400	450	500	≥500	N
JAN	.5	12	2	12	4	14	10	33	12	2								51
JAN	1.0	6	10	10	6	16	12	39	2									51
JAN	1.5	2	2	18	8	8	18	39	6									51
JAN	2.0	2		10	10	6	16	53	2	2								51
JAN	2.5	2		4	8	10	16	53	6									51
JAN	3.0		2	4	2	12	10	59	12									51
FEB	.5	2	3	11	8	8	10	32	16	3	10							63
FEB	1.0		5	5	10	5	5	40	22	10								63
FEB	1.5	3	3	5	5	6	10	33	32	3								63
FEB	2.0	3	2	6	3	5	10	38	32	2								63
FEB	2.5	2	2		3	10	8	51	25									63
FEB	3.0	2	2			8	14	52	22									63
MAR	.5	5	3	5	8	3	6	32	21	9	6	2		2				66
MAR	1.0	2	2	5	3	6	6	36	27	8	5							66
MAR	1.5	2	2	2	3	6	8	39	24	8	6							66
MAR	2.0	2	2		3	5	2	42	30	12	3							66
MAR	2.5	3			3	5	2	41	39	6								66
MAR	3.0	3				3	3	50	36	5								66
APR	.5	1	3	4		10	10	16	24	18	7	1	3					67
APR	1.0	1	1	1	1	4	7	15	28	21	10	7						67
APR	1.5	1	1	1		4	1	13	33	31	7	4						67
APR	2.0	1		1	3	1		16	51	19	4	1						67
APR	2.5		1				3	28	51	15	1							67
APR	3.0						6	43	43	7								67
MAY	.5	5	2		2	2	3	18	8	18	20	8	9	5		2		65
MAY	1.0	5				2		14	26	20	28	6	2					65
MAY	1.5				2		5	14	32	32	14	2						65
MAY	2.0			2		3		20	45	23	8							65
MAY	2.5		2			2	2	37	42	17								65
MAY	3.0	2				2	8	51	37	2								65
JUN	.5	4				2		14	18	18	12	8	10	4	6	2		49
JUN	1.0	2	2			2		10	29	22	16	14	2					49
JUN	1.5			2	2		2	22	43	24	4							49
JUN	2.0		2		2		4	45	43	4								49
JUN	2.5	2		8	2	8	10	51	22									49
JUN	3.0	2	6	2	4	12	12	51	10									49
JUL	.5	5			2		3	10	23	18	13	5	8	7	3		2	60
JUL	1.0		2				3	22	28	27	18	5	2					60
JUL	1.5		2		2	3	2	32	43	15	2							60
JUL	2.0		2	2		12	7	57	18	3								60
JUL	2.5		3	3	17	10	15	45	7									60
JUL	3.0	5	3	8	22	25	13	22	2									60
AUG	.5			3	2	2	3	17	30	12	18	7	3	3	2	2		60
AUG	1.0	2			3	2	2	30	27	23	10		2					60
AUG	1.5	2	3		5	2	3	52	27	5	2							60
AUG	2.0	5	3		5	10	13	55	8									60
AUG	2.5	7	2	3	13	15	22	38										60
AUG	3.0	7	10	12	22	17	17	17										60
SEP	.5	2	8		8		8	32	20	22	2							50
SEP	1.0			2	8	8	6	40	36	2								50
SEP	1.5			4		10	18	58	10									50
SEP	2.0		4	4	10	18	12	50	2									50
SEP	2.5	2	8	12	16	10	26	26										50
SEP	3.0	8	4	18	18	28	10	14										50
OCT	.3	5	2	7	5	7	5	30	25	7	4	2						56
OCT	1.0	2	4	4	9	7	7	52	16									56
OCT	1.5	2	2	5	4	13	14	55	5									56
OCT	2.0	2	4	5	11	23	18	38										56
OCT	2.5	4	2	13	27	11	25	20										56
OCT	3.0	2	9	18	25	23	7	18										56
NOV	.5	2	9	9	11	13	15	23	15	9								47
NOV	1.0	2		2	19	11	13	38	13	2								47
NOV	1.5	2	4	2	11	17	21	36	6									47
NOV	2.0	2	2	11	19	2	32	32										47
NOV	2.5	2	6	6	17	21	21	23	2									47
NOV	3.0	4	4	4	23	30	19	13	2									47
DEC	.5	4	7	15	9	13	9	35	7	2								46
DEC	1.0		7	13	4	11	11	41	13									46
DEC	1.5		7	13	4	11	9	43	13									46
DEC	2.0		7	11	4	15	9	46	9									46
DEC	2.5		4	4	13	9	13	48	9									46
DEC	3.0		4	7	9	9	17	46	9									46

Table 6h.

0-10N

MONTH	LAYER	<-100	-60	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5						17	17	50		17							6
JAN	1.0							33	67									6
JAN	1.5							17	83									6
JAN	2.0							33	67									6
JAN	2.5							33	67									6
JAN	3.0							33	67									6
FEB	.5						43	43			14							7
FEB	1.0							71	29									7
FEB	1.5							29	71									7
FEB	2.0							43	57									7
FEB	2.5							29	71									7
FEB	3.0							29	71									7
MAR	.5				8			23	54	15								13
MAR	1.0						8	38	54									13
MAR	1.5							62	38									13
MAR	2.0							62	38									13
MAR	2.5							69	31									13
MAR	3.0							69	31									13
APR	.5						17	25	42	17								12
APR	1.0						8	42	42	8								12
APR	1.5						17	25	50	8								12
APR	2.0						8	42	50									12
APR	2.5							58	42									12
APR	3.0						8	67	25									12
MAY	.5				7	7	14	21	21	14		7		7				14
MAY	1.0		7			7	7	29	50									14
MAY	1.5						14	29	57									14
MAY	2.0							57	43									14
MAY	2.5							57	43									14
MAY	3.0							43	57									14
JUN	.5							20	27	13		13	20	7				15
JUN	1.0						7	20	27	20	20	7						15
JUN	1.5						7	20	47	20	7							15
JUN	2.0							20	60	13	7							15
JUN	2.5							20	73	7								15
JUN	3.0							20	73	7								15
JUL	.5			2		3	11	20	50	11	3	2						66
JUL	1.0					2	6	36	41	11	2		3					66
JUL	1.5					2	3	36	50	6		3						66
JUL	2.0						3	24	68	2	2	2						66
JUL	2.5						2	27	68	2	2							66
JUL	3.0					2		29	68		2							66
AUG	.5							86	14									7
AUG	1.0							57	43									7
AUG	1.5							43	57									7
AUG	2.0							57	43									7
AUG	2.5							71	29									7
AUG	3.0							86	14									7
SEP	.5					13		13	38	38								8
SEP	1.0						13	38	50									8
SEP	1.5							50	50									8
SEP	2.0							63	38									8
SEP	2.5							50	50									8
SEP	3.0							63	38									8
OCT	.5							13	38	25	25							8
OCT	1.0						13	25	38	25								8
OCT	1.5							25	75									8
OCT	2.0							38	63									8
OCT	2.5							50	50									8
OCT	3.0							38	63									8
NOV	.5			14		14	14	43	14									7
NOV	1.0						14	43	43									7
NOV	1.5							43	57									7
NOV	2.0							29	71									7
NOV	2.5							29	71									7
NOV	3.0							71	29									7
DEC	.5						29	14	43	14								7
DEC	1.0							57	43									7
DEC	1.5							57	43									7
DEC	2.0							57	43									7
DEC	2.5							57	43									7
DEC	3.0							57	43									7

Table 7a.

10-20N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5																	0
JAN	1.0																	0
JAN	1.5																	0
JAN	2.0																	0
JAN	2.5																	0
JAN	3.0																	0
FEB	.5																	0
FEB	1.0																	0
FEB	1.5																	0
FEB	2.0																	0
FEB	2.5																	0
FEB	3.0																	0
MAR	.5								50	50								2
MAR	1.0								50	50								2
MAR	1.5								50	50								2
MAR	2.0								50	50								2
MAR	2.5								100									2
MAR	3.0								100									2
APR	.5										100							1
APR	1.0									100								1
APR	1.5									100								1
APR	2.0								100									1
APR	2.5								100									1
APR	3.0								100									1
MAY	.5																	0
MAY	1.0																	0
MAY	1.5																	0
MAY	2.0																	0
MAY	2.5																	0
MAY	3.0																	0
JUN	.5		25						50		25							4
JUN	1.0		25						50	25								4
JUN	1.5				25				50	25								4
JUN	2.0							25	75									4
JUN	2.5								100									4
JUN	3.0								100									4
JUL	.5								100									1
JUL	1.0								100									1
JUL	1.5								100									1
JUL	2.0								100									1
JUL	2.5								100									1
JUL	3.0								100									1
AUG	.5								50	50								2
AUG	1.0								50	50								2
AUG	1.5								50	50								2
AUG	2.0							50		50								2
AUG	2.5							50	50									2
AUG	3.0						50		50									2
SEP	.5							50	50									2
SEP	1.0							50	50									2
SEP	1.5							50	50									2
SEP	2.0							50	50									2
SEP	2.5								100									2
SEP	3.0								100									2
OCT	.5								100									1
OCT	1.0								100									1
OCT	1.5								100									1
OCT	2.0								100									1
OCT	2.5								100									1
OCT	3.0								100									1
NOV	.5								100									1
NOV	1.0								100									1
NOV	1.5								100									1
NOV	2.0								100									1
NOV	2.5								100									1
NOV	3.0								100									1
DEC	.5							50	50									2
DEC	1.0							50	50									2
DEC	1.5							50	50									2
DEC	2.0							50	50									2
DEC	2.5							50	50									2
DEC	3.0							50	50									2

Table 7b.

20-30N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5							17	33	33	8		8					12
JAN	1.0							17	58	8	17							12
JAN	1.5							50	33	17								12
JAN	2.0							50	33	17								12
JAN	2.5							58	33	8								12
JAN	3.0							67	33									12
FEB	.5						7	13	40	33		7						15
FEB	1.0							40	40	20								15
FEB	1.5							27	73									15
FEB	2.0							47	53									15
FEB	2.5							53	47									15
FEB	3.0							60	40									15
MAR	.5			5		5	5	32	26	11	11			5				19
MAR	1.0							26	63	5	5							19
MAR	1.5							37	47	16								19
MAR	2.0							42	42	16								19
MAR	2.5						5	37	47	11								19
MAR	3.0							42	47	11								19
APR	.5					5	5	19	48	10	5	10						21
APR	1.0					5	5	33	43	10	5							21
APR	1.5				5		5	29	57	5								21
APR	2.0				5			43	52									21
APR	2.5					5		48	48									21
APR	3.0					5		62	33									21
MAY	.5							30	26	13	9	9		13				23
MAY	1.0							17	22	39	13	9						23
MAY	1.5							26	43	22	4		4					23
MAY	2.0					4	4	30	39	13	4		4					23
MAY	2.5					4	4	39	30	13		9						23
MAY	3.0						4	48	22	17		9						23
JUN	.5							28	28	11	6	11	6	11				18
JUN	1.0							11	50	11	17			11				18
JUN	1.5							33	39	6	17	6						18
JUN	2.0						6	33	33	22	6							18
JUN	2.5					6		44	22	17	11							18
JUN	3.0						6	44	22	17	11							18
JUL	.5					5	11	26	21	21	11		5					19
JUL	1.0					5	11	21	32	21	11							19
JUL	1.5					5	16	21	37	11	11							19
JUL	2.0						21	26	32	16	5							19
JUL	2.5						11	37	37	11	5							19
JUL	3.0						11	47	26	11	5							19
AUG	.5			5	5		16	11	26	21		16						19
AUG	1.0						16	26	42	16								19
AUG	1.5						11	26	58	5								19
AUG	2.0						11	37	53									19
AUG	2.5						5	47	47									19
AUG	3.0							53	47									19
SEP	.5						7	21	50	14	7							14
SEP	1.0							43	50	7								14
SEP	1.5							36	64									14
SEP	2.0							64	36									14
SEP	2.5							79	21									14
SEP	3.0							79	21									14
OCT	.5			5	5	5		19	52	10		5						21
OCT	1.0					5		24	57	14								21
OCT	1.5						5	24	67	5								21
OCT	2.0						10	29	57	5								21
OCT	2.5					5	5	29	62									21
OCT	3.0						10	33	57									21
NOV	.5						13	26	39	9		9		4				23
NOV	1.0						9	48	26	17								23
NOV	1.5							52	43	4								23
NOV	2.0							52	43	4								23
NOV	2.5							52	43	4								23
NOV	3.0							43	52	4								23
DEC	.5				5		9	18	45	14	5	5						22
DEC	1.0						5	41	41	9	5							22
DEC	1.5							73	18	9								22
DEC	2.0							55	45									22
DEC	2.5							59	41									22
DEC	3.0							64	36									22

Table 7c.

30-40N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5			1	1	1	7	23	30	10	14	4	1	8	1			159
JAN	1.0			1			4	26	35	16	9	6	2	1				159
JAN	1.5						1	35	40	11	9	2	1	1				159
JAN	2.0						3	33	45	13	4	1	1	1				159
JAN	2.5						2	37	44	13	2		1	1				159
JAN	3.0						1	40	47	9	1	1		1				159
FEB	.5		1		1	1	4	22	24	13	11	10	6	6	2		1	126
FEB	1.0					1	2	27	29	18	7	6	2	6	2			126
FEB	1.5						3	29	37	10	8	5	5	4				126
FEB	2.0						1	33	43	6	8	6	2	2				126
FEB	2.5							39	37	12	6	6		1				126
FEB	3.0							40	38	14	6	1		1				126
MAR	.5					1	6	24	22	14	5	8	4	15	2			185
MAR	1.0					1	6	29	22	18	7	6	4	7				185
MAR	1.5					1	6	32	30	14	6	8	3	2				185
MAR	2.0					2	3	38	29	14	9	3	1					185
MAR	2.5			1		1	3	43	30	16	5	2	1					185
MAR	3.0		1				4	45	31	14	4	1						185
APR	.5	1			2	3	5	20	18	16	10	5	4	10	4	3	1	154
APR	1.0		1			3	6	16	28	17	8	7	5	5	5			154
APR	1.5				1	1	5	23	29	17	8	7	2	7	1			154
APR	2.0				1	1	3	28	35	14	6	6	3	4				154
APR	2.5					1	3	32	37	11	9	3	3	1				154
APR	3.0					1	4	29	45	14	3	3	1	1				154
MAY	.5	2	1	1	1	2	2	14	27	11	6	4	8	18	3	1	1	179
MAY	1.0	1			1		5	16	29	13	8	6	4	12	3			179
MAY	1.5		1				5	18	38	13	9	4	6	9	1			179
MAY	2.0			1			4	23	37	14	5	6	6	4				179
MAY	2.5					1	4	28	38	13	7	5	2	2				179
MAY	3.0						3	33	39	13	7	2	3					179
JUN	.5		2			1	3	18	35	9	12	4	4	7	4		1	142
JUN	1.0		1			1	5	18	38	14	8	4	4	5	1	1		142
JUN	1.5				1	1	3	21	43	15	8	3	3	4				142
JUN	2.0						2	23	51	12	5	3	1	4				142
JUN	2.5						3	27	50	11	4	3	2	1				142
JUN	3.0						2	30	49	12	3	3	1					142
JUL	.5		2	1	1	8	8	14	38	12	7	1	3	8				113
JUL	1.0		1	2	1	3	5	19	42	12	4	4	4	3				113
JUL	1.5		1			3	8	19	45	10	9	4	1	1				113
JUL	2.0		1			1	6	27	48	8	8	1		1				113
JUL	2.5				1		5	36	42	12	2	1	1					113
JUL	3.0						5	42	42	8	2	1						113
AUG	.5		2		1	1	13	23	36	15	4	2	2	3				115
AUG	1.0		1		1		9	30	38	17	3		2					115
AUG	1.5		1		2	1	10	31	37	14	3	2						115
AUG	2.0		1			3	12	33	36	14	1	1						115
AUG	2.5		1		1	1	6	42	43	5	1	1						115
AUG	3.0	1				1	6	40	49	3	1							115
SEP	.5			1		1	8	28	35	13	10	4		1				113
SEP	1.0					2	7	28	44	13	–	1						113
SEP	1.5						4	40	44	10	2							113
SEP	2.0					1	3	38	52	6								113
SEP	2.5					1	5	36	53	4	1							113
SEP	3.0						3	39	52	5	1							113
OCT	.5				2	1	1	30	40	13	4	5	1	4			1	150
OCT	1.0				1	1	1	35	38	14	7	1	1	1			1	150
OCT	1.5					1	1	35	43	12	5	1	1				1	150
OCT	2.0					1	1	36	45	11	3	2					1	150
OCT	2.5						3	38	45	10	1	2				1		150
OCT	3.0						3	42	47	5	3				1			150
NOV	.5		1				6	18	41	20	9	2	1	2				140
NOV	1.0		1				4	21	41	22	7	1	1	1				140
NOV	1.5			1	1		1	25	46	19	4	1	1	1				140
NOV	2.0					1	1	28	49	15	4	1	1					140
NOV	2.5					1	2	34	47	13	3	1						140
NOV	3.0						1	39	49	9	1							140
DEC	.5				1	1	7	29	35	14	7	4	1	1				136
DEC	1.0				1	1	5	32	41	10	7	2	1	1				136
DEC	1.5				1	1	4	34	44	8	6	1		1				136
DEC	2.0					1	4	37	44	9	4	1	1					136
DEC	2.5						4	41	46	5	4	1						136
DEC	3.0						3	44	45	6	1	1						136

Table 7d.

40-50N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5		1			1	3	20	27	16	9	7	5	8	2		1	224
JAN	1.0						3	26	31	18	9	5	2	4	1			224
JAN	1.5						1	32	39	11	7	5	1	3				223
JAN	2.0						1	37	40	11	6	3	1					223
JAN	2.5							42	39	12	4	2						223
JAN	3.0							46	39	12	2							223
FEB	.5			1	2	1	2	16	28	15	8	7	4	11	2	1		205
FEB	1.0				1	2	2	19	29	18	8	6	4	9	1			205
FEB	1.5						3	22	36	13	10	7	2	6				205
FEB	2.0						4	26	37	15	8	5	1	3				205
FEB	2.5						1	33	39	15	5	2	1	1				205
FEB	3.0						1	39	37	15	5	1	1					205
MAR	.5					2	4	18	17	11	9	10	7	16	3	1	2	247
MAR	1.0						5	19	25	17	12	8	6	6	2	1		247
MAR	1.5						2	27	30	17	11	5	3	3	1	1		247
MAR	2.0						2	33	33	16	8	2	2	2	1			247
MAR	2.5						2	37	38	14	2	4	1	2				247
MAR	3.0						2	42	40	9	2	2	1	1				247
APR	.5		1		1	2	5	16	15	9	9	5	7	19	9	2	1	232
APR	1.0		1			1	3	21	19	11	11	9	7	11	3	1		232
APR	1.5					1	4	22	26	13	10	9	4	7	3			232
APR	2.0					1	3	28	29	15	8	6	3	6				232
APR	2.5					1	3	32	34	11	8	3	3	4				232
APR	3.0						3	36	36	10	6	5	1	2				232
MAY	.5		1	1		2	3	12	12	9	9	7	6	27	5	3		202
MAY	1.0						3	16	18	12	11	8	9	19	2	1		202
MAY	1.5					1	3	16	23	15	14	11	4	9	2			202
MAY	2.0						3	19	26	24	11	6	2	7				202
MAY	2.5						1	22	37	20	8	3	2	6				202
MAY	3.0						3	26	41	16	4	3	3	2				202
JUN	.5	1	4	1	3	2	5	9	12	7	9	10	4	22	6	2	1	161
JUN	1.0		1	2	1	2	6	11	21	17	11	6	5	14	1	2		161
JUN	1.5				1	2	5	19	27	17	5	10	2	11	2			161
JUN	2.0					2	2	22	37	13	8	4	7	5	1			161
JUN	2.5						4	22	39	13	8	7	4	3				161
JUN	3.0						2	29	39	12	10	3	2	3				161
JUL	.5		1	1	1	2	6	19	21	15	6	3	4	16	4			202
JUL	1.0			1		1	6	21	25	16	10	6	3	8	1			202
JUL	1.5			1	1		4	25	32	17	7	4	4	4				202
JUL	2.0					1	6	25	40	14	4	4	2	1				202
JUL	2.5					1	6	30	41	12	6	2	1	1				202
JUL	3.0					1	5	37	42	9	4	1		1				202
AUG	.5	1	1	1	1	2	6	22	21	13	10	4	5	11	2		1	163
AUG	1.0				1	2	7	25	27	13	8	2	6	7	1			163
AUG	1.5				1	2	7	31	28	14	6	6	2	3				163
AUG	2.0			1		1	7	35	29	15	7	3	1	1				163
AUG	2.5				1		4	40	34	15	4	1		1				163
AUG	3.0						4	42	38	12	2		1	1				163
SEP	.5		1	1	1	2	7	21	28	10	10	8	6	6		1		177
SEP	1.0		1			2	6	23	32	12	11	6	3	5				177
SEP	1.5				1	1	2	33	32	16	8	3	3	2				177
SEP	2.0						4	32	39	14	7	2	2					177
SEP	2.5						3	36	45	10	6	1						177
SEP	3.0						2	39	46	10	3							177
OCT	.5		2	1	1	2	3	23	26	18	10	6	3	5	2			187
OCT	1.0			1	1	1	2	29	31	19	10	5	2	1				187
OCT	1.5					1	3	33	40	17	4	1	1	1				187
OCT	2.0						2	37	47	10	2	1	1					187
OCT	2.5						2	40	52	4	1	1	1					187
OCT	3.0						1	43	52	2	1	1						187
NOV	.5						2	23	32	18	10	4	5	5				203
NOV	1.0						1	29	36	15	9	5	2	2				203
NOV	1.5						1	37	34	16	6	2	1	1				203
NOV	2.0						1	44	39	10	3	1						203
NOV	2.5						1	49	40	8	2							203
NOV	3.0					1	1	52	37	7	1							203
DEC	.5						5	17	30	16	12	8	3	8	1			229
DEC	1.0						3	22	37	18	11	4	4	2				229
DEC	1.5							29	38	18	10	3						229
DEC	2.0						1	34	45	14	5							229
DEC	2.5							41	43	11	3							229
DEC	3.0						1	45	44	8	1	1						229

Table 7e.

50-60N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5		1			1	3	24	29	18	10	5	3	7	1	1		196
JAN	1.0					1	2	26	32	19	12	3	3	4				196
JAN	1.5						2	28	38	19	7	4	2	2				196
JAN	2.0						2	34	37	16	6	3	1	1				196
JAN	2.5						2	40	39	13	5	2		1				196
JAN	3.0						3	39	41	13	3	1	1					196
FEB	.5		2	1	1	1	8	24	32	11	5	7	4	6	1	1		194
FEB	1.0				1	2	5	25	37	13	7	4	2	5				194
FEB	1.5					1	4	29	42	10	7	4	2	2				194
FEB	2.0					1	3	35	42	10	2	4	2	1				194
FEB	2.5					1	2	40	42	9	2	4	1	1				194
FEB	3.0				1	1	2	45	41	6	4	1		1				194
MAR	.5		1		1	1	3	20	24	10	9	7	5	13	4	1	2	196
MAR	1.0				1	1	2	23	24	13	11	9	3	12	2		1	196
MAR	1.5				1		3	24	30	13	11	8	2	7	1			196
MAR	2.0				1		3	27	34	15	9	5	4	3				196
MAR	2.5				1		2	32	37	14	7	5	1	3				196
MAR	3.0					1	2	36	40	11	7	1	2	2				196
APR	.5		1	1	1	1	5	18	19	14	7	9	7	12	4	1	1	181
APR	1.0					2	4	22	21	17	8	10	6	9	1	1		181
APR	1.5						5	24	25	19	12	7	3	4	1			181
APR	2.0					1	3	26	34	20	7	5	2	2	1			181
APR	2.5					1	2	31	37	18	8	3	1	2				181
APR	3.0						3	34	44	12	5	1	1	2				181
MAY	.5		2	1	1	1	4	14	18	9	7	6	4	18	7	4	3	180
MAY	1.0			1	1	1	4	17	21	12	13	4	7	16	4	1		180
MAY	1.5			1	1	1	3	21	23	16	12	6	4	13	2			180
MAY	2.0			1		1	3	24	29	17	6	6	6	7				180
MAY	2.5					1	2	30	30	16	8	5	5	3				180
MAY	3.0					1	3	32	32	15	9	4	2	2				180
JUN	.5			1		1	4	13	12	13	10	7	7	18	9	4	1	163
JUN	1.0		1		1	1	6	13	14	17	9	13	4	20	1	1		163
JUN	1.5		1	1		2	5	14	22	19	10	11	7	9	1			163
JUN	2.0					2	6	20	25	18	13	8	4	6				163
JUN	2.5					1	3	19	36	20	10	6	3	2				163
JUN	3.0						3	25	36	20	6	6	2	2				163
JUL	.5			1	1	1	7	13	17	19	3	8	8	14	5	2	1	178
JUL	1.0				1	1	4	17	25	13	8	8	7	13	2			178
JUL	1.5					1	6	20	26	19	8	6	4	12				178
JUL	2.0					1	8	21	31	16	8	7	4	4	1			178
JUL	2.5					1	6	26	32	17	8	6	1	2	1			178
JUL	3.0						6	28	38	16	8	2		2				178
AUG	.5		3	1	2	3	5	22	26	11	8	6	3	6	3	1		249
AUG	1.0		1		1	2	7	25	27	14	7	3	3	8				249
AUG	1.5					2	7	27	32	16	6	2	3	4				249
AUG	2.0					1	8	31	34	15	5	2	2	2				249
AUG	2.5						4	35	40	13	4	1	1	1				249
AUG	3.0						3	40	41	10	2	1	2					249
SEP	.5			1	1	2	1	23	28	15	9	6	5	8	1	2		162
SEP	1.0					1	1	25	32	14	11	7	4	3	1			162
SEP	1.5					1	1	30	34	16	9	4	2	2				162
SEP	2.0					1	2	30	39	16	8	2	2					162
SEP	2.5						4	35	36	20	4	2						162
SEP	3.0					1	3	39	39	15	2	1						162
OCT	.5				1		5	26	29	18	8	3	4	7				175
OCT	1.0						3	31	31	17	9	2	2	3				175
OCT	1.5					1	3	33	40	14	4	3	1	2				175
OCT	2.0					1	3	38	39	11	4	1	2					175
OCT	2.5						2	46	39	7	3	2						175
OCT	3.0						2	51	38	8	3							175
NOV	.5		1	1	1	1	3	28	37	14	5	4	2	3	2			174
NOV	1.0			1	1		3	32	36	16	4	4	2	2				174
NOV	1.5			1			1	36	41	14	2	5	1	1				174
NOV	2.0					1	2	38	42	11	5		1	1				174
NOV	2.5						1	48	39	9	2	1	1					174
NOV	3.0							52	37	10	1	1						174
DEC	.5		2			1	3	31	29	18	6	3	1	5	1	1		175
DEC	1.0		1			1	4	34	33	15	5	1	1	5				175
DEC	1.5		1	1		1	3	38	38	11	5	3	1	1				175
DEC	2.0				1	1	2	39	39	13	4	1	1	1				175
DEC	2.5					1	2	45	38	10	3		1					175
DEC	3.0					1	1	50	41	5	2	1						175

Table 7f.

60-70N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	50	100	150	200	≥200	N
JAN	.5							25	50				25					4
JAN	1.0							50	25	25								4
JAN	1.5							25	50	25								4
JAN	2.0							50	25	25								4
JAN	2.5							50	25		25							4
JAN	3.0							50	25	25								4
FEB	.5								33			33		33				3
FEB	1.0								33	33	33							3
FEB	1.5							33	33	33								3
FEB	2.0							33	67									3
FEB	2.5							33	67									3
FEB	3.0							33	67									3
MAR	.5									25		38	13	25				8
MAR	1.0								13	50	13			25				8
MAR	1.5								38	38		25						8
MAR	2.0								50	25	13	13						8
MAR	2.5							13	38	38	13							8
MAR	3.0							13	63	13	13							8
APR	.5							11		11	11	11	11	44				9
APR	1.0						11		22	11	11	22	11	11				9
APR	1.5					11	11		22	22	22			11				9
APR	2.0							11	44	33		11						9
APR	2.5							11	67	11	11							9
APR	3.0							11	78		11							9
MAY	.5	9					9		9	36		18					18	11
MAY	1.0						9	9		36	9	9		18			9	11
MAY	1.5						9	9	18	18	18	9		9			9	11
MAY	2.0						9	18	18	9	27			9	9			11
MAY	2.5						9	9	18	45				18				11
MAY	3.0						9		45	27		9		9				11
JUN	.5								17	17			17	25	8	17		12
JUN	1.0							8	17	25	8		8	33				12
JUN	1.5						8		33	17		25	8	8				12
JUN	2.0						8	8	33	8	33		8					12
JUN	2.5							17	50	17	17							12
JUN	3.0							17	58	25								12
JUL	.5		11			5		16		5	16	11		21		5	11	19
JUL	1.0		11				5	21	16		16	5		16	5	5		19
JUL	1.5			11				26	5	11	21	11		5	11			19
JUL	2.0					11		21	11	21	21			11	5			19
JUL	2.5						11	16	21	32	5	5	5	5				19
JUL	3.0						5	21	32	26		11		5				19
AUG	.5						25		13	13		13	13	25				8
AUG	1.0						25		13	25		25	13					8
AUG	1.5						13	13		50		25						8
AUG	2.0						13		25	13	38	13						8
AUG	2.5							13	38	13	38							8
AUG	3.0								50	50								8
SEP	.5	13					13	13		13				50				8
SEP	1.0							38		13	13		25	13				8
SEP	1.5							13	13	38	13		13		13			8
SEP	2.0							13	13	50		13		13				8
SEP	2.5							13	25	38	13			13				8
SEP	3.0							25	38	25				13				8
OCT	.5						20		40		20				20			5
OCT	1.0						20	20			40			20				5
OCT	1.5						20	20		20	20			20				5
OCT	2.0							40		20	20			20				5
OCT	2.5							40	20	20		20						5
OCT	3.0							20	60			20						5
NOV	.5							14	29		14	14	29					7
NOV	1.0							14	29	29	29							7
NOV	1.5							29	43	14	14							7
NOV	2.0							29	57	14								7
NOV	2.5							29	57	14								7
NOV	3.0							43	57									7
DEC	.5		11	11			11		22			22	11	11				9
DEC	1.0			11		11	11	11	22	11		22						9
DEC	1.5					11	22		44		11	11						9
DEC	2.0						11	33	33	11	11							9
DEC	2.5						11	33	33	22								9
DEC	3.0						11	22	56	11								9

Table 7g.

70-80N

MONTH	LAYER	<-100	-50	-40	-30	-20	-10	0	10	20	30	40	60	100	150	200	≥200	N
JAN	.5		2			2	2	20	27	18	4	10		14	2			51
JAN	1.0				2		2	24	29	18	4	10	2	12				51
JAN	1.5						2	25	35	15	4	8	4	6				51
JAN	2.0							31	35	16	4	10	4					51
JAN	2.5							35	39	10	8	6	2					51
JAN	3.0							39	37	14	4	6						51
FEB	.5			2			3	24	26	13	6	8	6	8	5			63
FEB	1.0					2	3	24	33	11	5	10	5	5	3			63
FEB	1.5						3	24	33	17	5	8	6	3				63
FEB	2.0						3	25	40	13	6	8	2	3				63
FEB	2.5						2	30	40	11	10	6		2				63
FEB	3.0							35	43	10	8	3	2					63
MAR	.5		2		2	2		23	24	11	20	5	9	5				66
MAR	1.0					2	2	23	29	18	17	6	5					66
MAR	1.5					2		24	38	21	11	5						66
MAR	2.0					2	2	27	44	15	9	2						66
MAR	2.5							38	39	15	6	2						66
MAR	3.0							39	45	9	5		2					66
APR	.5						3	19	26	12	10	7	6	15	1			67
APR	1.0						1	21	27	18	12	6	4	10				67
APR	1.5				1		1	19	36	16	9	10	4	1				67
APR	2.0					1	1	19	39	18	13	6	1					67
APR	2.5						3	22	45	16	9	4						67
APR	3.0						1	24	54	13	6	1						67
MAY	.5			2		3	3	5	34	11	9	9	5	12	5	2	2	65
MAY	1.0			2		3	5	11	37	17	6	2	5	14				65
MAY	1.5						3	17	46	14	3	2	9	6				65
MAY	2.0						2	18	51	11	5	9	3	2				65
MAY	2.5						2	23	45	15	9	6						65
MAY	3.0							31	38	22	5	5						65
JUN	.5				2		2	14	12	12	8	8		24	10	6		49
JUN	1.0							12	18	16	12	10	6	18	4			49
JUN	1.5						2	12	27	16	16	10		14	2			49
JUN	2.0						2	24	27	18	10	6	6	6				49
JUN	2.5						8	20	33	20	8	4	4	2				49
JUN	3.0						4	31	37	14	8	4	2					49
JUL	.5		2		2		[illegible]	7	8	15	7	3	7	25	13	2	3	60
JUL	1.0		2		3	[illegible]		2	10	15	5	8	13	23	2			60
JUL	1.5			2			[illegible]	[illegible]	17	20	18	12	5	12				60
JUL	2.0						[illegible]	[illegible]	27	23	12	10	7	3				60
JUL	2.5					3	[illegible]	15	28	28	12	5	2	5				60
JUL	3.0					2		18	38	22	12	2	2	3				60
AUG	.5		2		3	2	5	8	22	10	10	12	5	13	5	3		60
AUG	1.0				2		5	15	25	17	5	15	7	8	2			60
AUG	1.5					2	2	15	35	17	17	8	3		2			60
AUG	2.0					2	3	13	50	13	12	5		2				60
AUG	2.5						7	22	45	17	7		2	2				60
AUG	3.0						7	22	48	17	3	2	2					60
SEP	.5					6	4	10	26	6	14	8	14	12	2			50
SEP	1.0					4	2	12	32	10	10	16	12	2				50
SEP	1.5							24	34	14	20	4	2	2				50
SEP	2.0							16	50	18	10		4					50
SEP	2.5				2		2	18	56	16	2	4						50
SEP	3.0					2	2	22	52	18	4							50
OCT	.5				2			23	25	13	13	4	5	16				56
OCT	1.0							23	30	14	14	7	5	5				56
OCT	1.5							30	30	18	11	5	2	4				56
OCT	2.0							32	34	21	7	5						56
OCT	2.5							36	38	21	5							56
OCT	3.0							36	39	20	5							56
NOV	.5				4		4	23	36	15	6	4	2	2	2			47
NOV	1.0		2				6	23	36	17	2	2	2	6				47
NOV	1.5				2		2	32	38	13	4	6		2				47
NOV	2.0						2	34	45	13	4	2						47
NOV	2.5						2	36	45	11	4							47
NOV	3.0						2	36	51	6	4							47
DEC	.5						2	41	37	7	2		2	9				46
DEC	1.0						7	37	39	7		2	2	7				46
DEC	1.5							50	39		4		4	2				46
DEC	2.0							50	39	4	2	2	2					46
DEC	2.5							54	37	4	2	2						46
DEC	3.0							61	33	4	2							46

Table 7h.

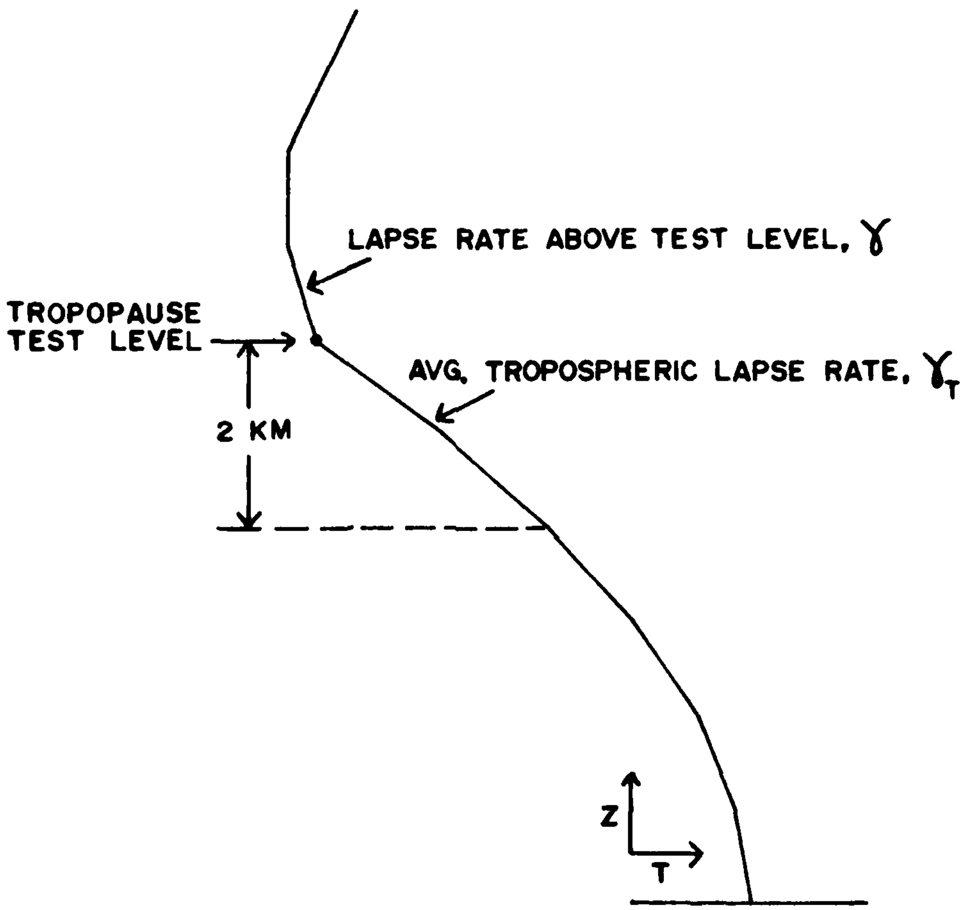
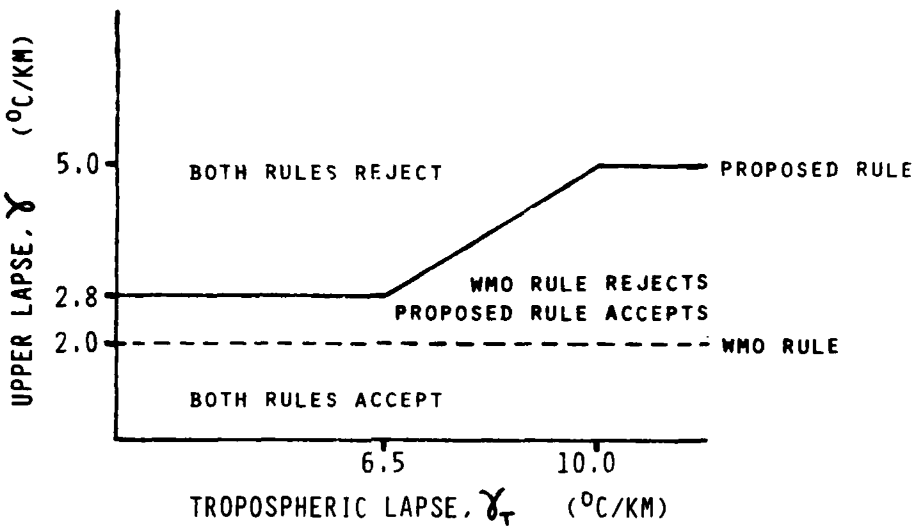


Figure 1. A temperature profile showing a level that is to be tested for tropopause using the criteria of Figure 2.

LAPSE RATE CRITERIA



PROPOSED RULE:

IF $\gamma > 5.0\ ^{o}C/KM$, REJECT

IF $\gamma < 2.8\ ^{o}C/KM$, ACCEPT

IF $2.8 \leq \gamma \leq 5.0$, ACCEPT IF:

$$\gamma \leq 0.63\gamma_T - 1.29$$

Figure 2. Graphical representation of tropopause lapse rate criteria showing regions of acceptance and rejection for the WMO and proposed tropopause (see text).

Figures 3a - 3l. Long-term monthly mean maps of tropopause height in kilometers. Dashed lines indicate analyses extapolated through regions of no data.

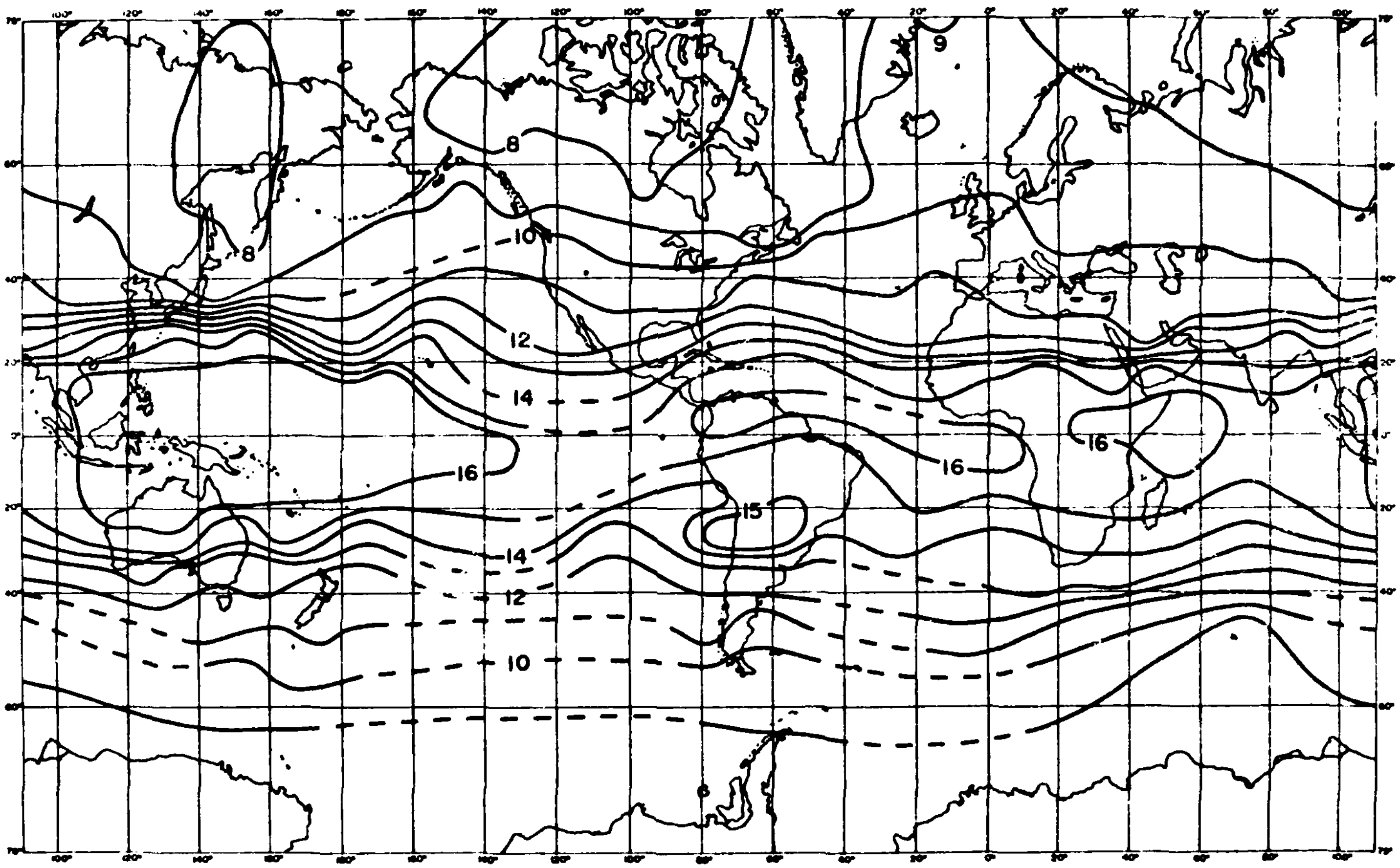


Figure 3a, January.

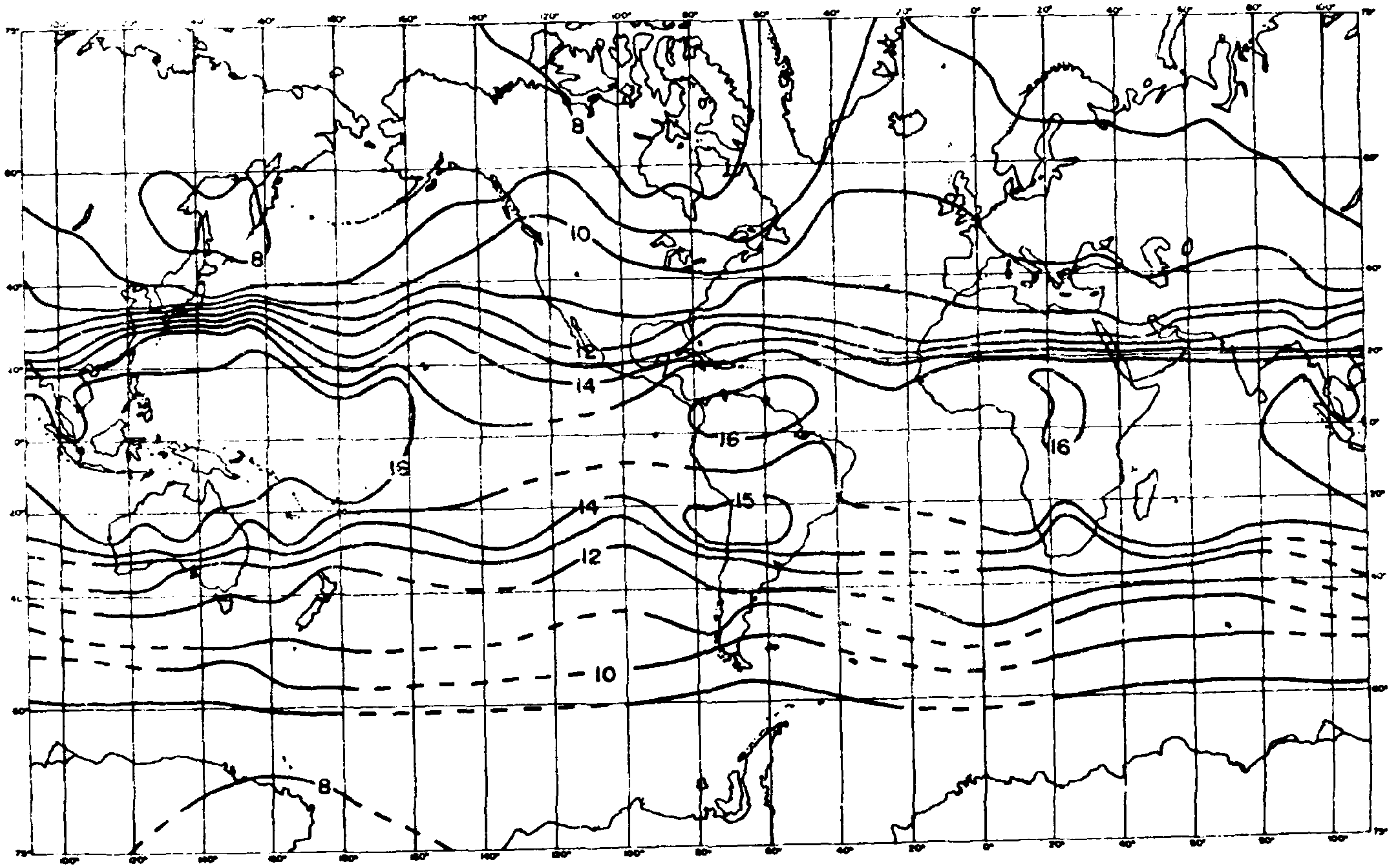


Figure 3b, February.

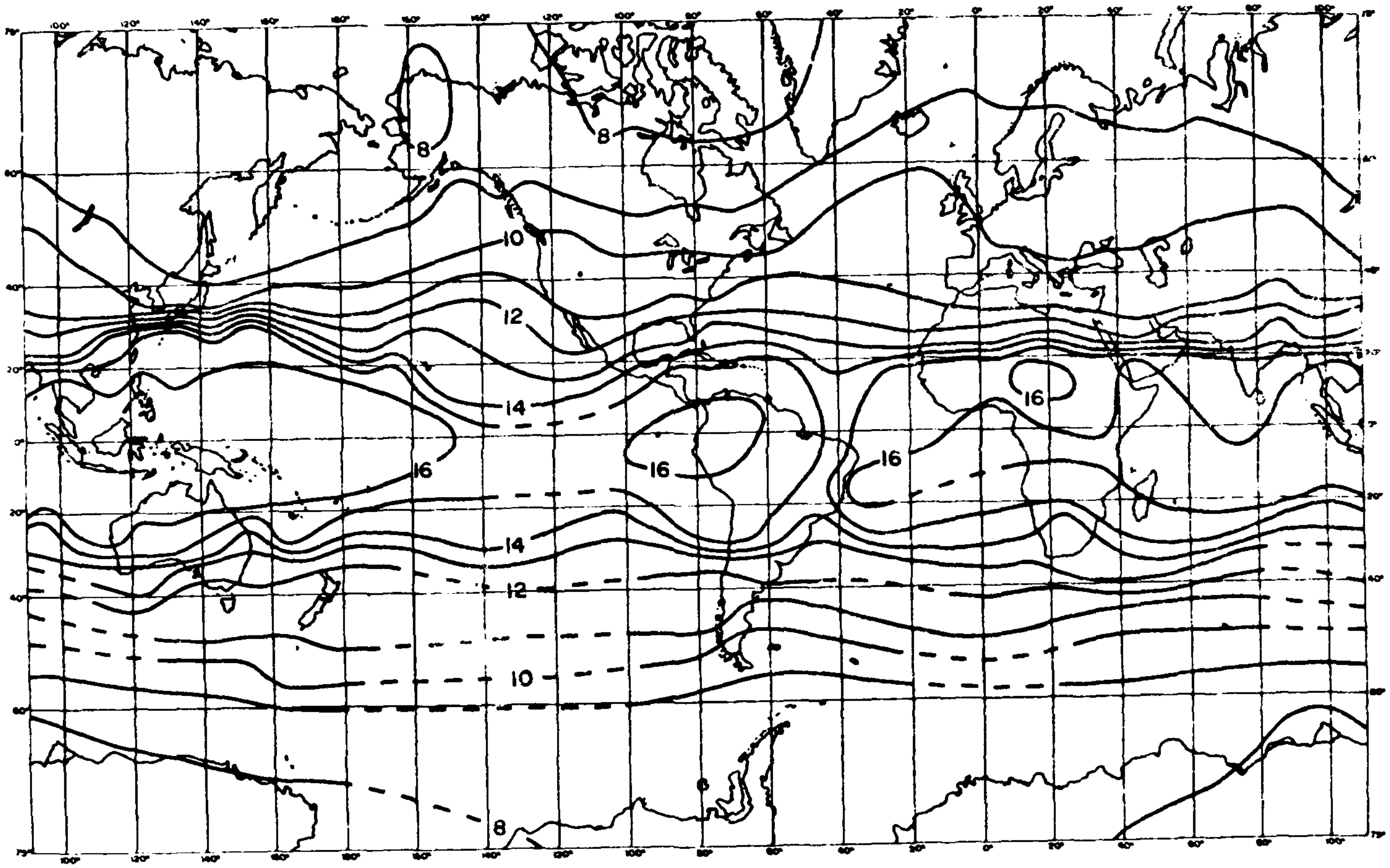


Figure 3c, March.

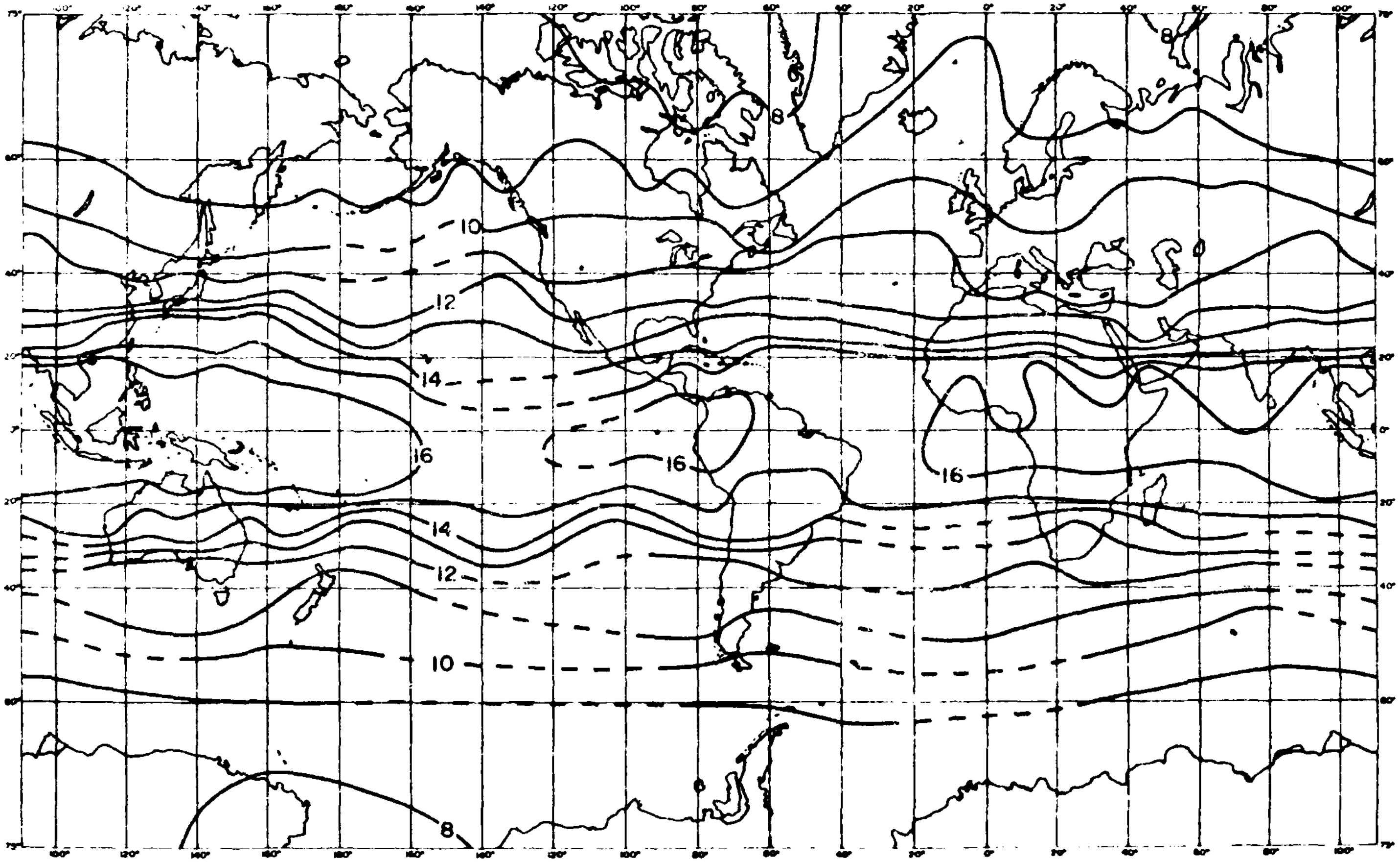


Figure 3d, April.

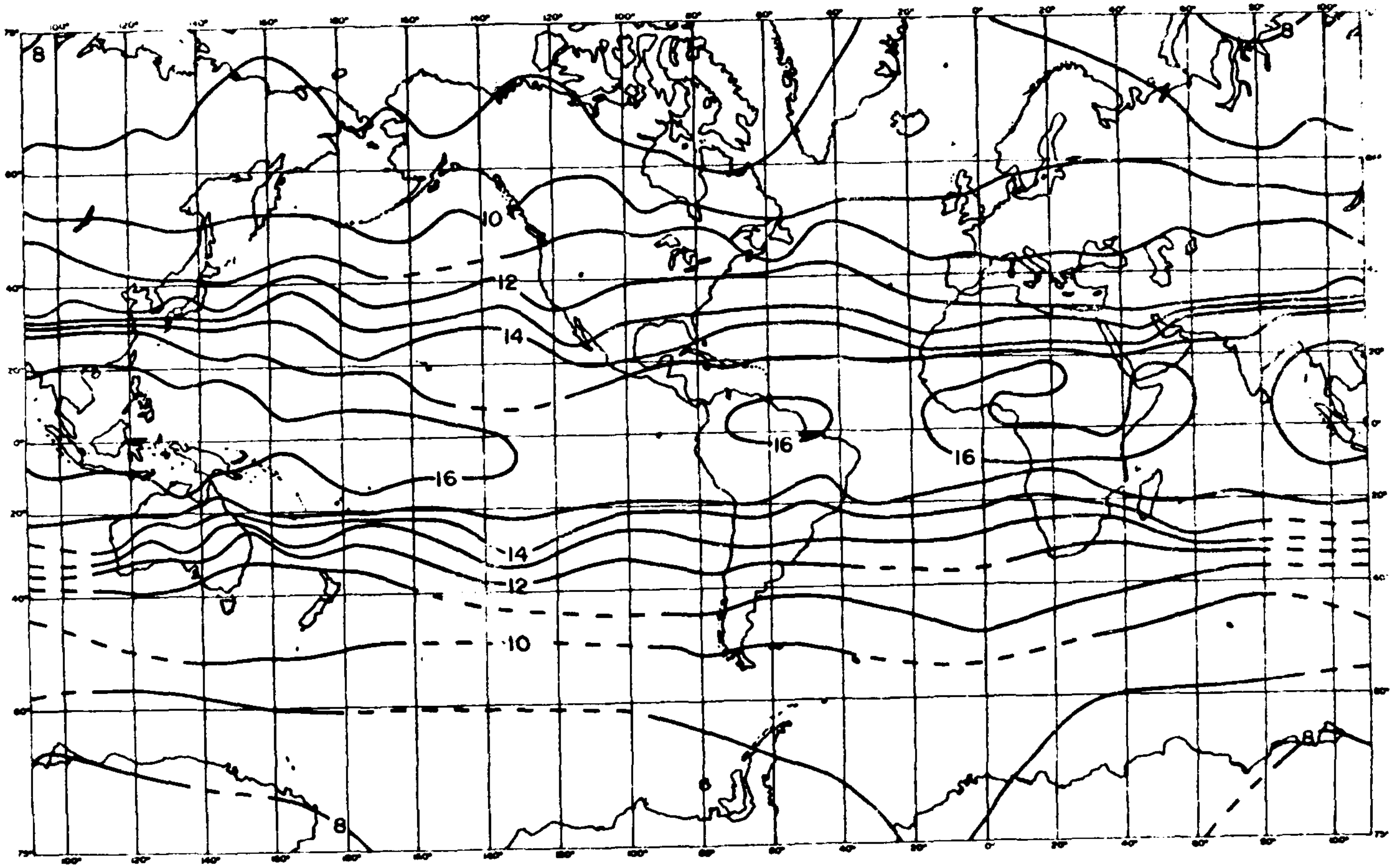


Figure 3e, May.

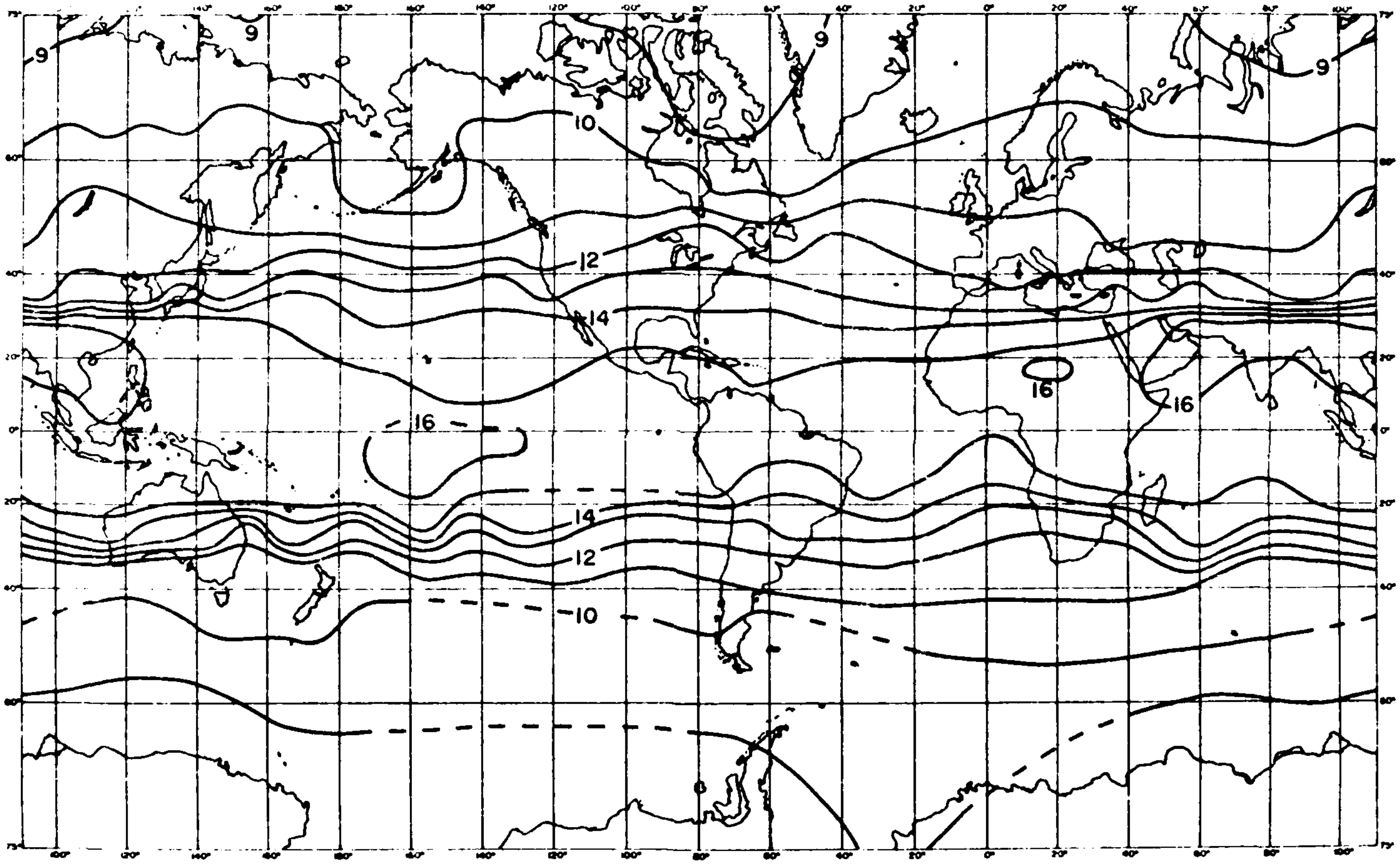


Figure 31, June.

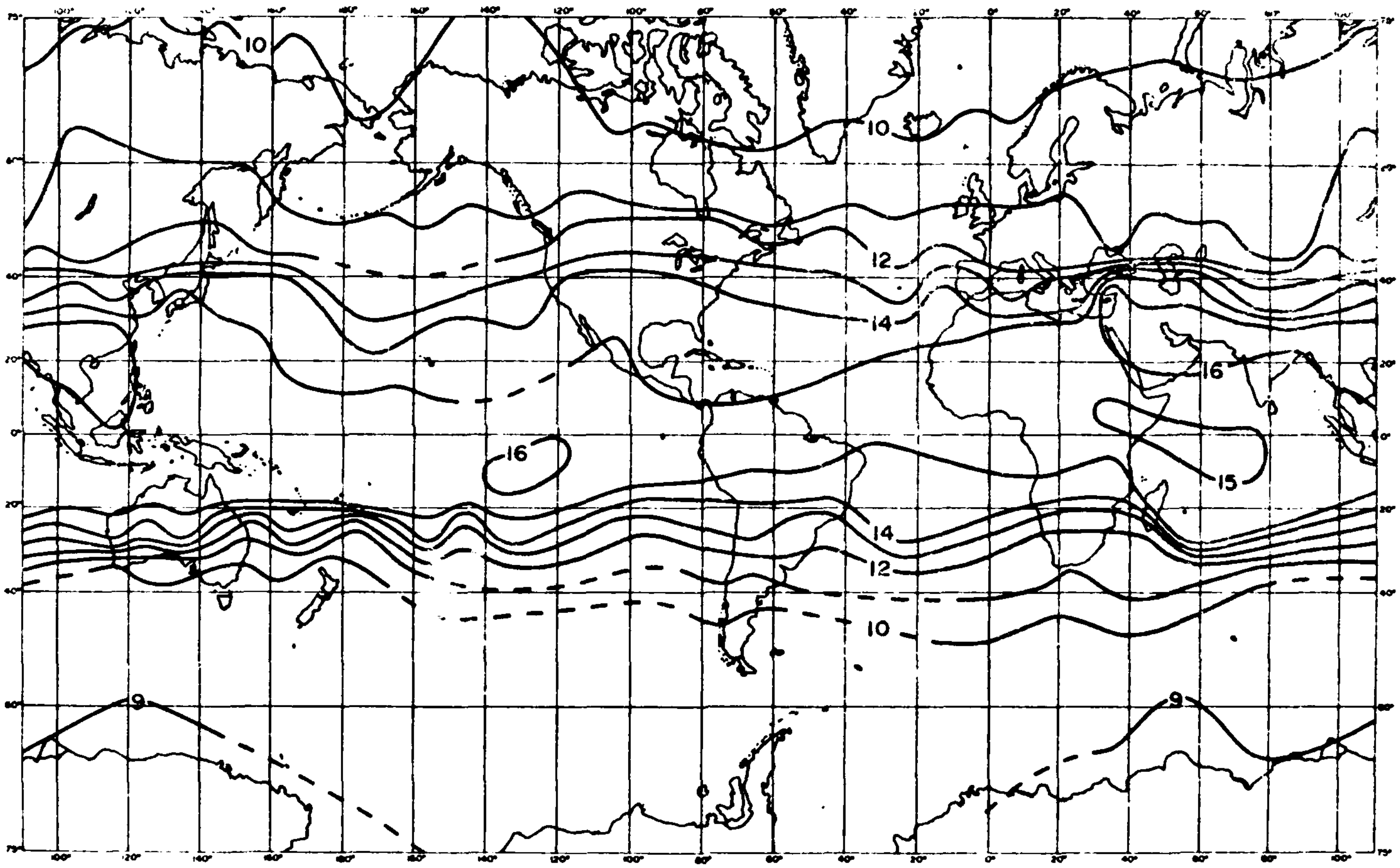


Figure 3g, July.

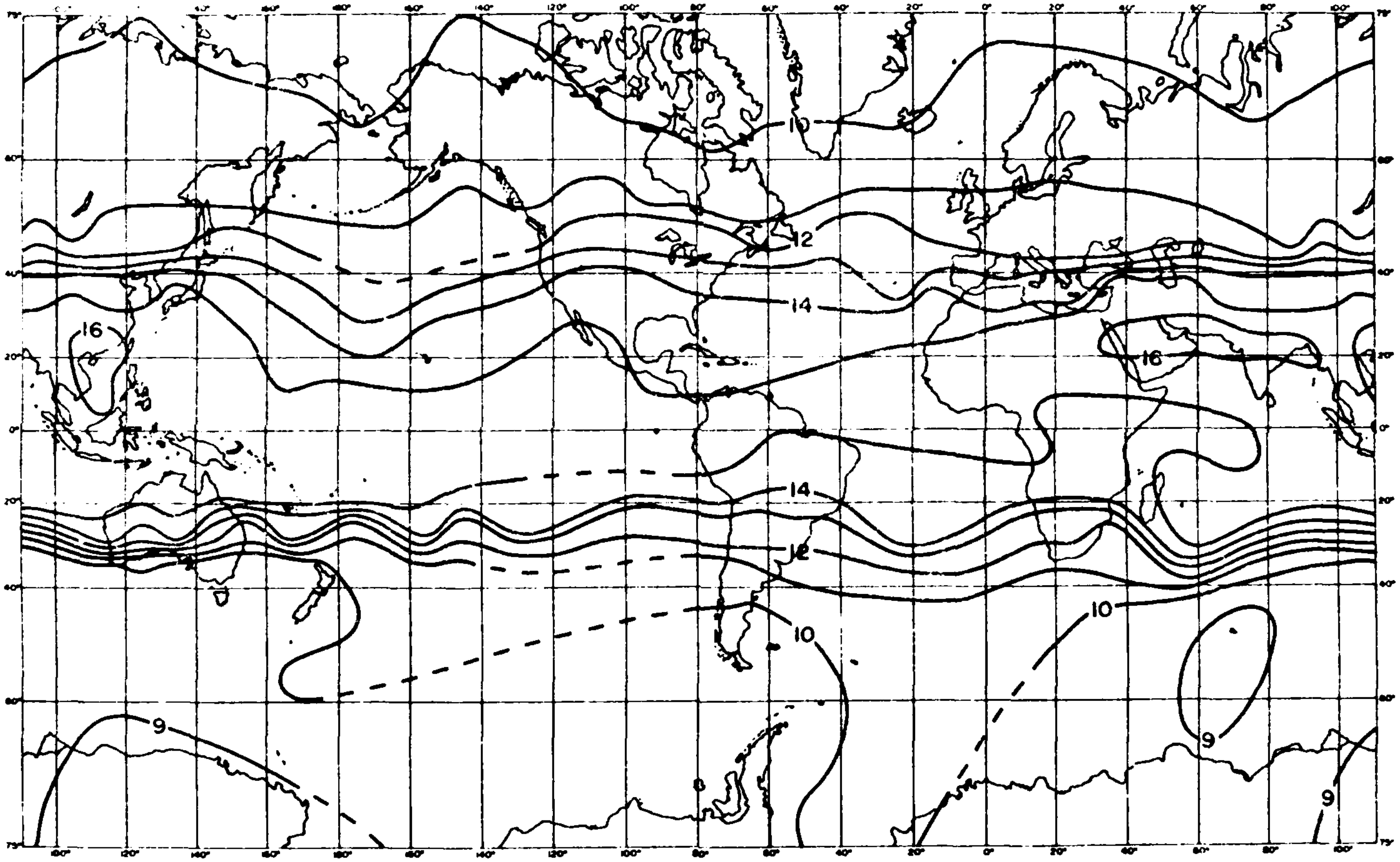


Figure 3h, August.

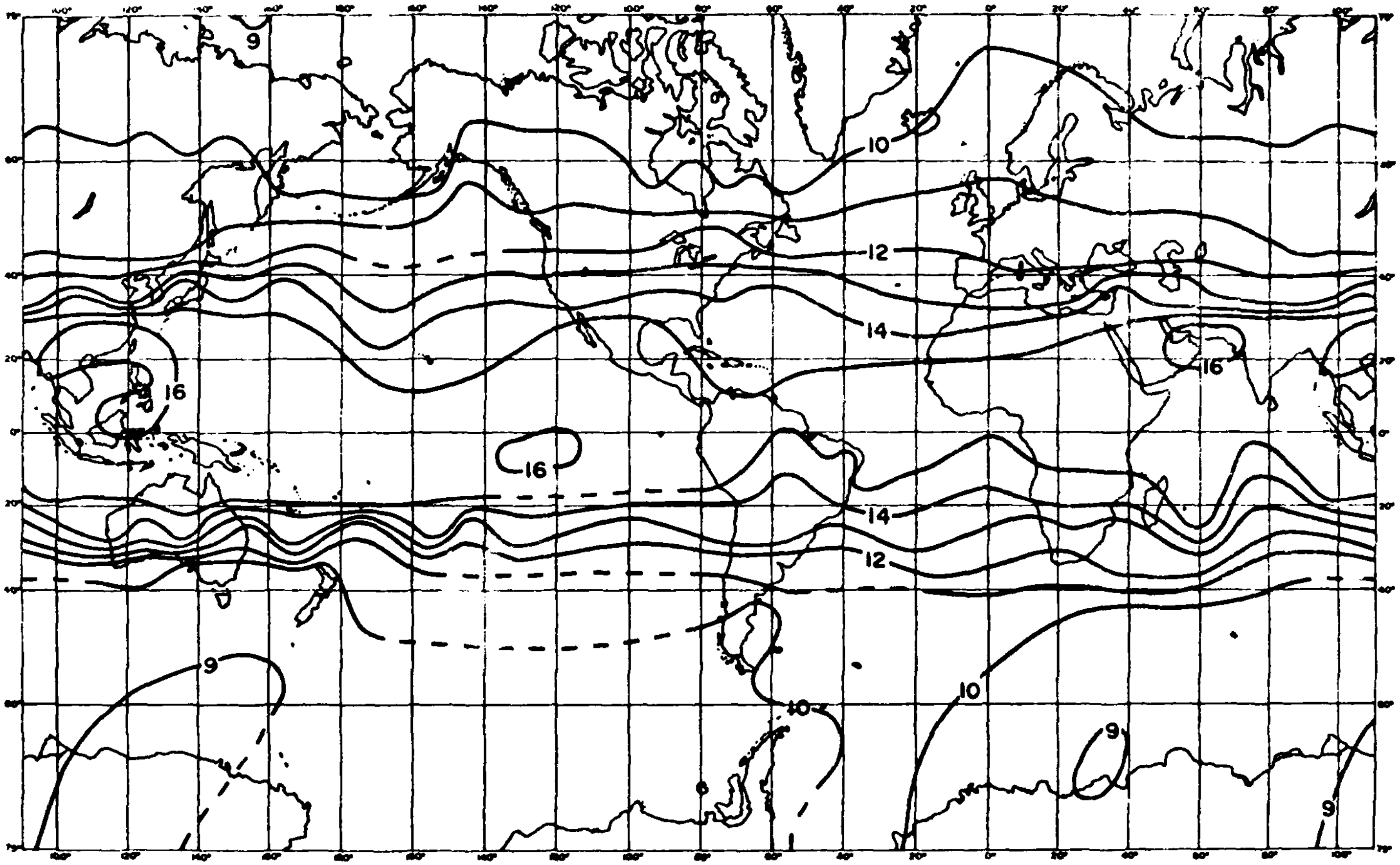


Figure 3i, September.

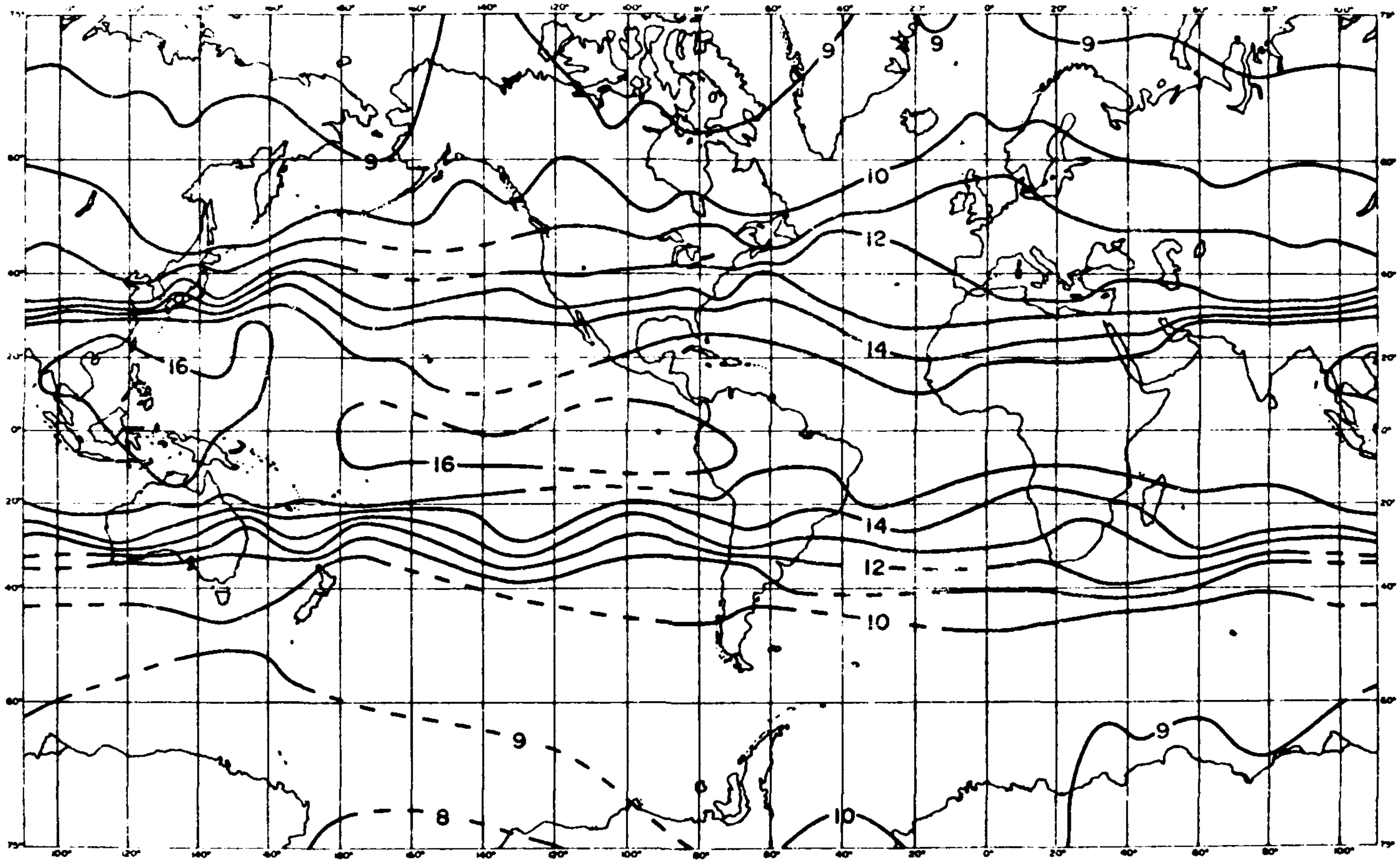


Figure 3j. October.

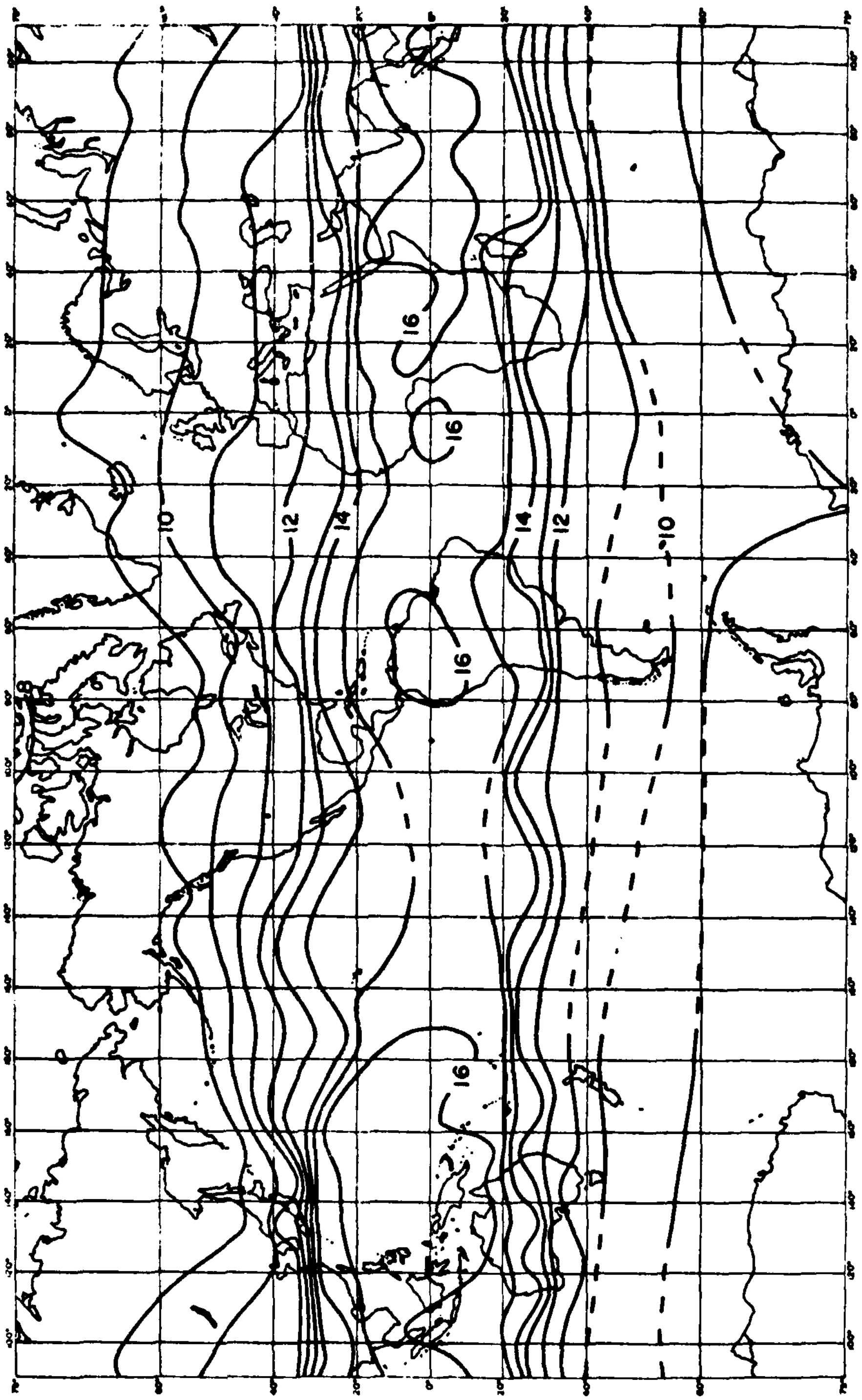


Figure 3k, November.

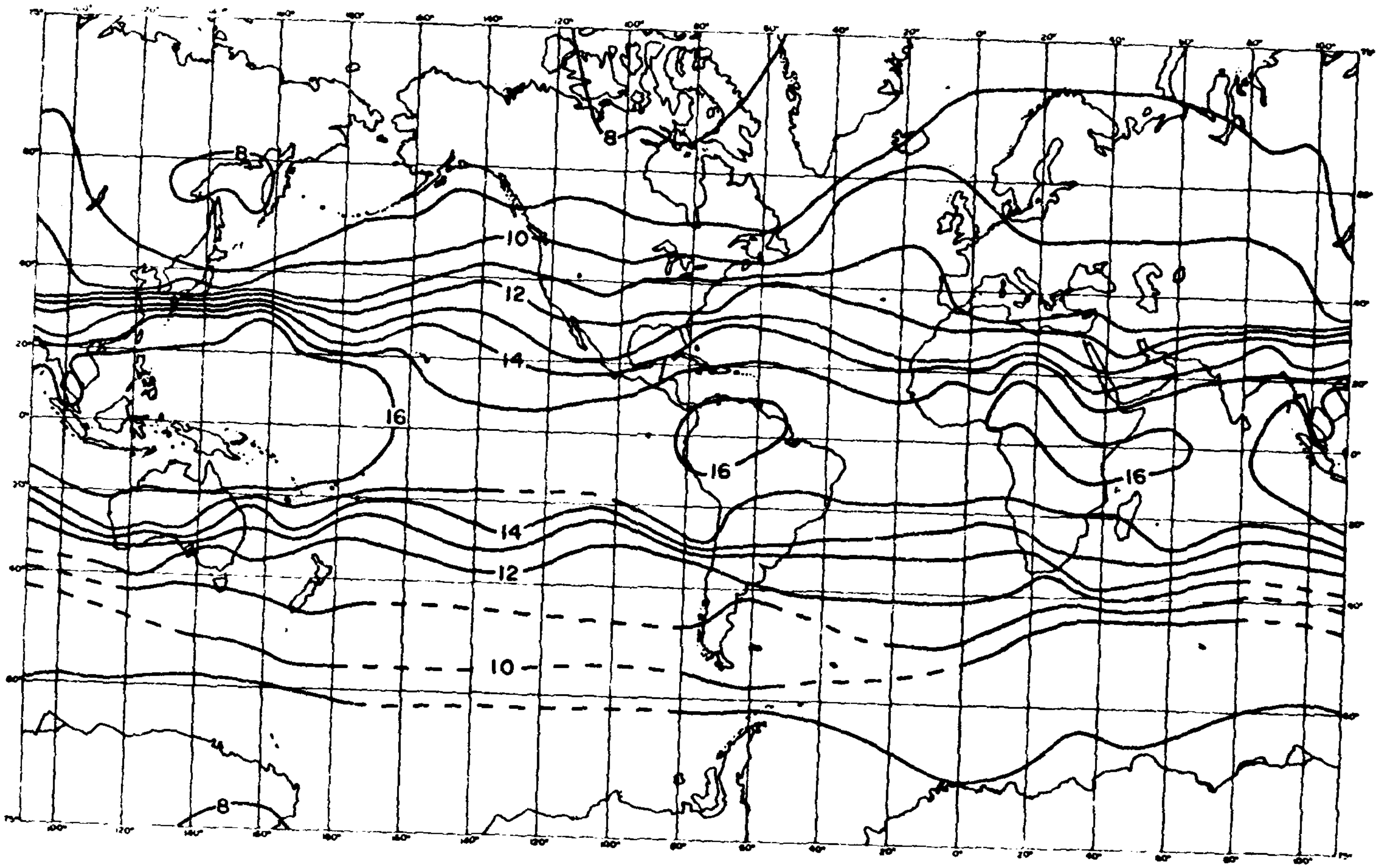


Figure 31, December.

Figures 4a - 4l. Monthly tropopause height frequency distributions for the period of record in the Northern Hemisphere. The numbers directly beneath the latitude belt designation are, in order, the total number of profiles, the mean tropopause height (km), and the standard deviation (km).

Figures 5a - 5l. Same as Figures 4a - 4l except for the Southern Hemisphere.

JANUARY (1964-1973)

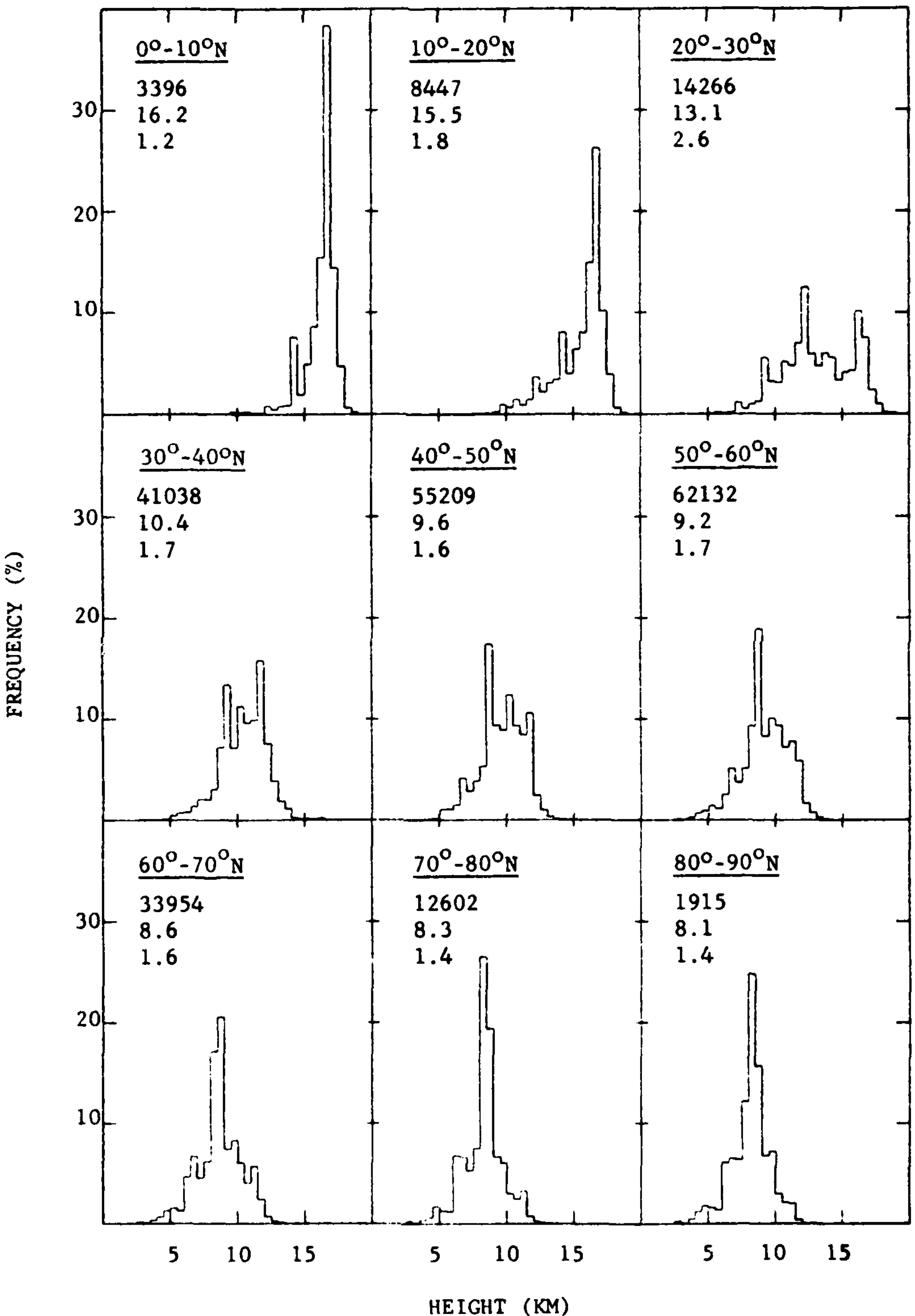


Figure 4a.

FEBRUARY (1964-1973)

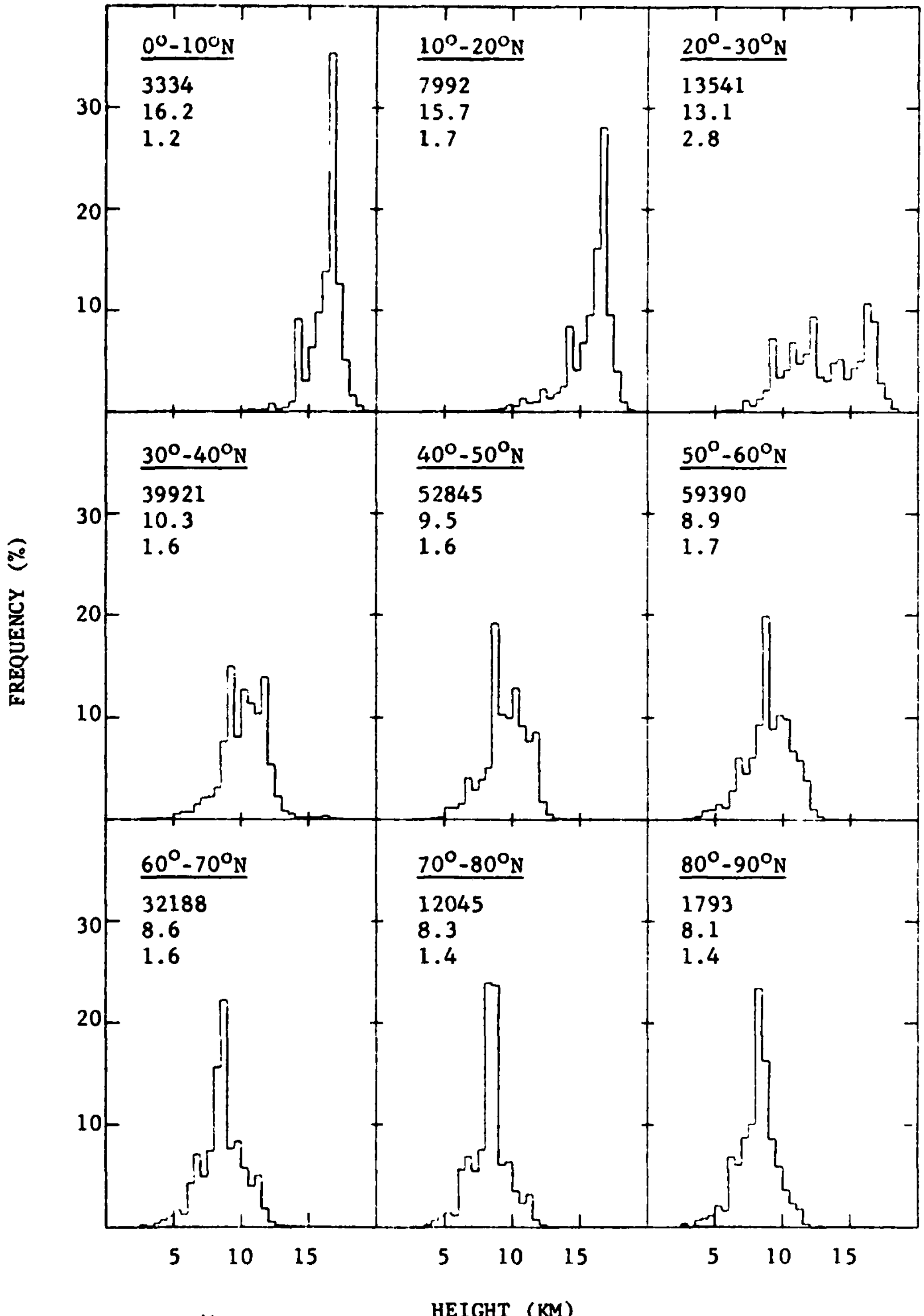


Figure 4b.

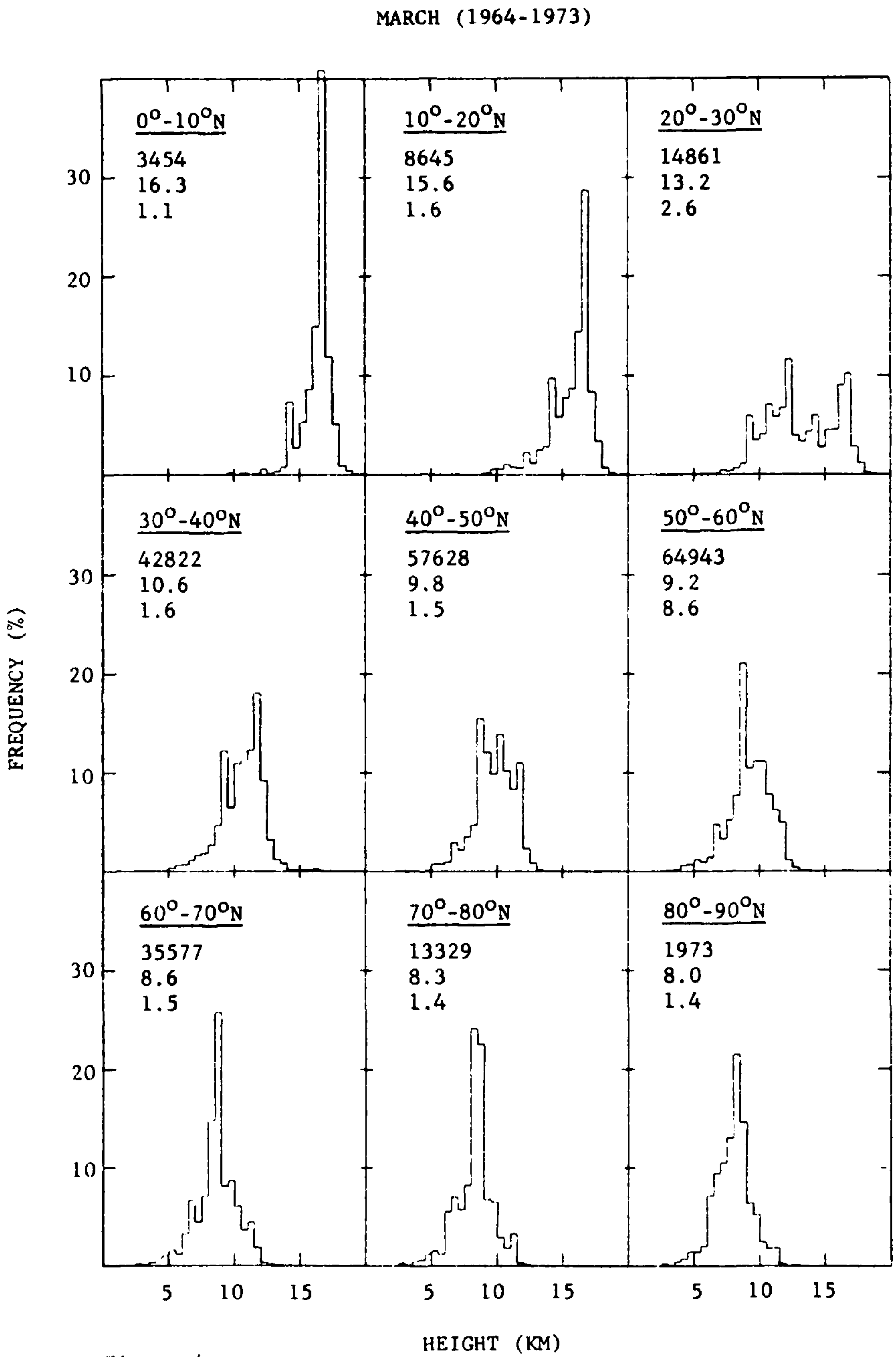

MARCH (1964-1973)
0°-10°N
3454
16.3
1.1
10°-20°N
8645
15.6
1.6
20°-30°N
14861
13.2
2.6
30°-40°N
42822
10.6
1.6
40°-50°N
57628
9.8
1.5
50°-60°N
64943
9.2
8.6
60°-70°N
35577
8.6
1.5
70°-80°N
13329
8.3
1.4
80°-90°N
1973
8.0
1.4
FREQUENCY (%)
30
20
10
5
10
15
HEIGHT (KM)

Figure 4c.

APRIL (1964-1973)

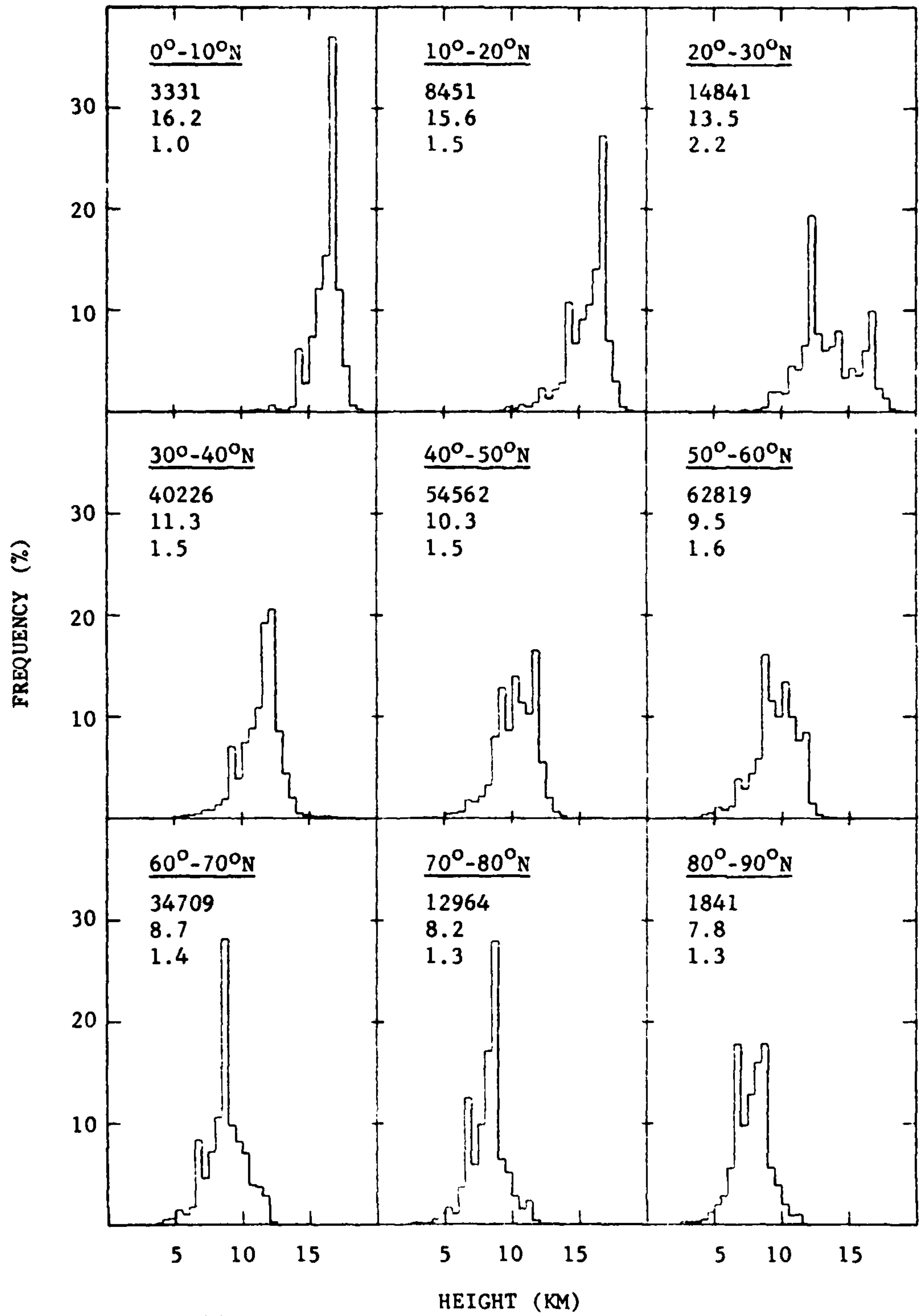


Figure 4d.

MAY (1964-1973)

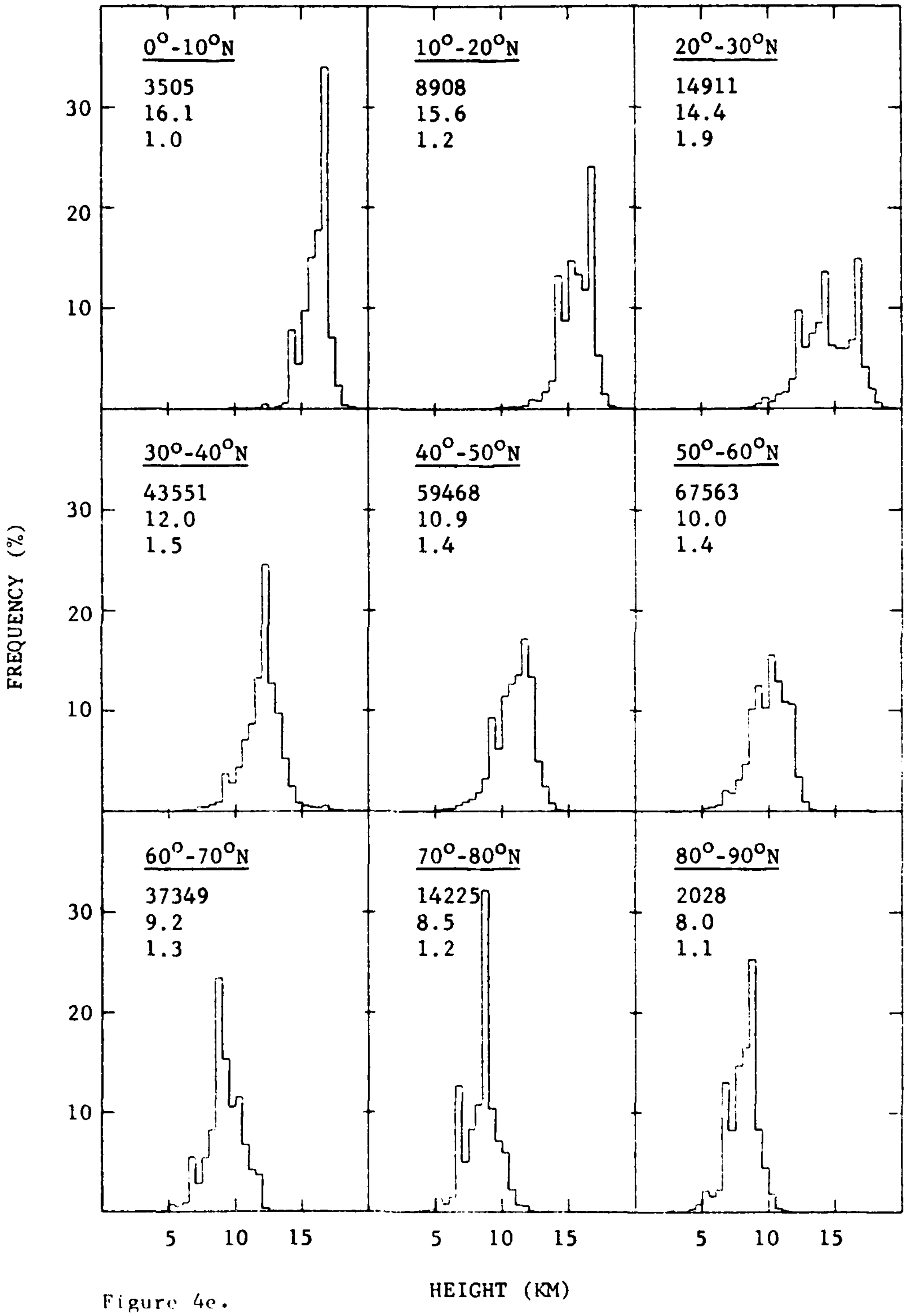


Figure 4e.

JUNE (1964-1973)

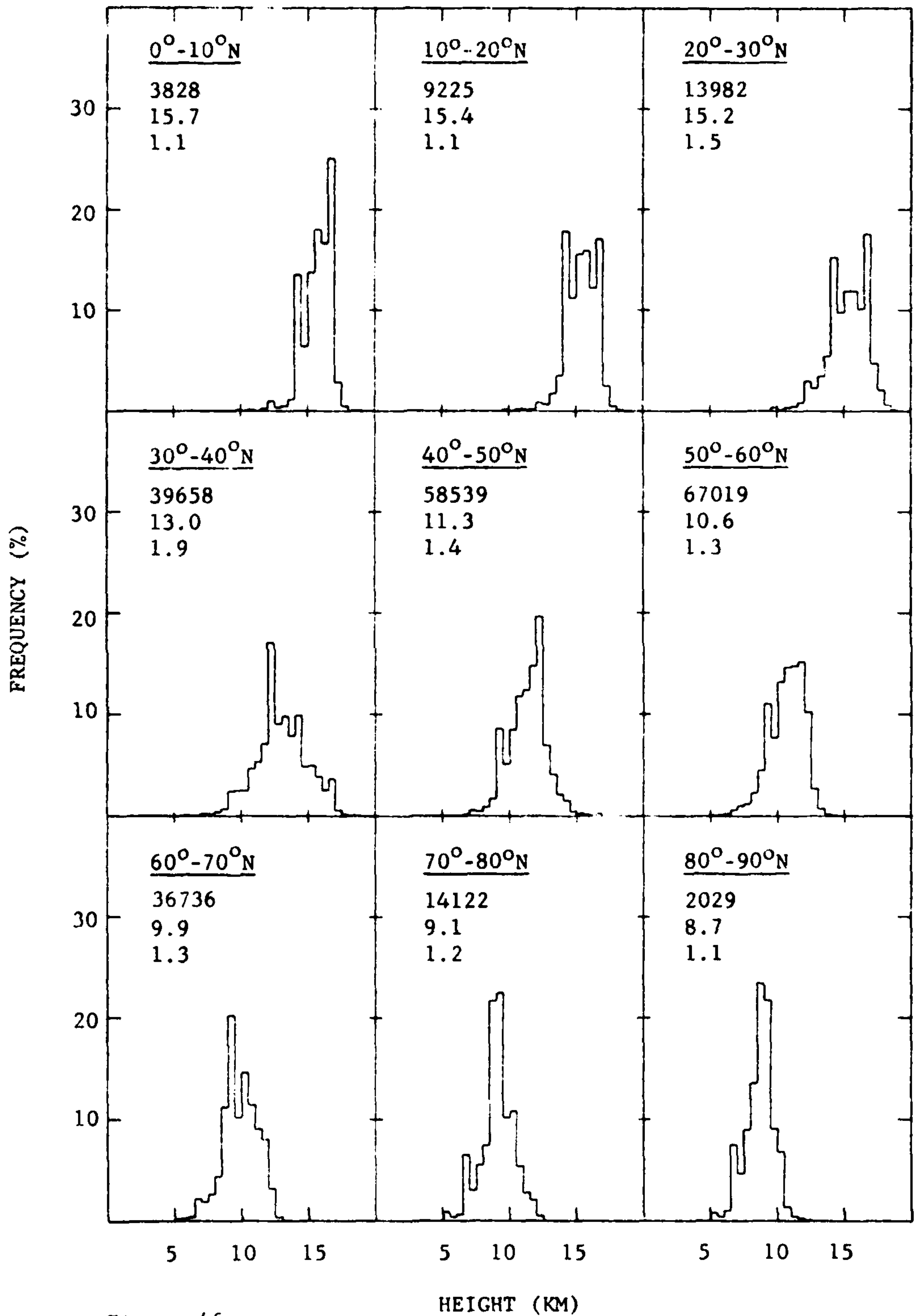


Figure 4f.

JULY (1964-1973)

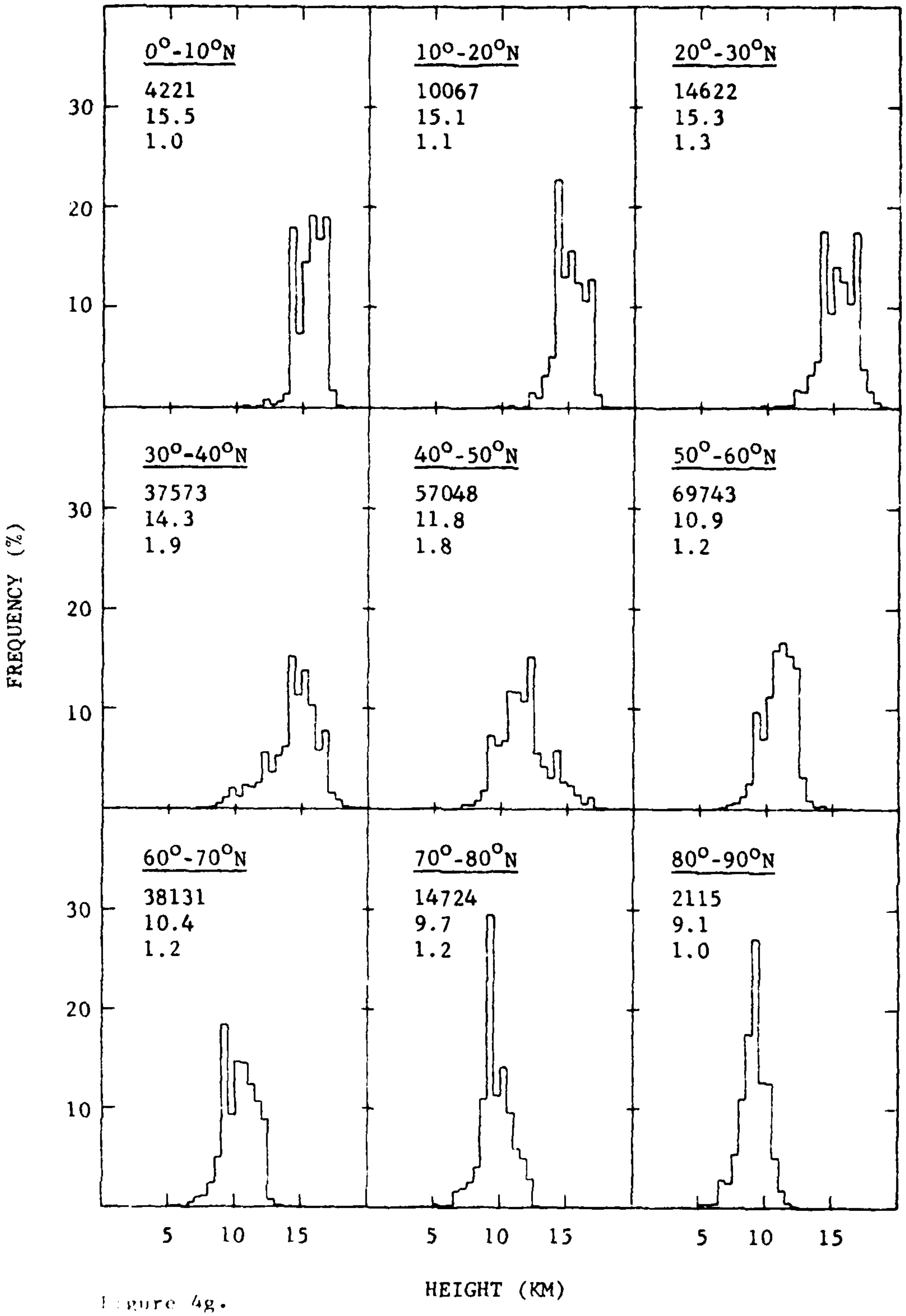


Figure 4g.

AUGUST (1964-1973)

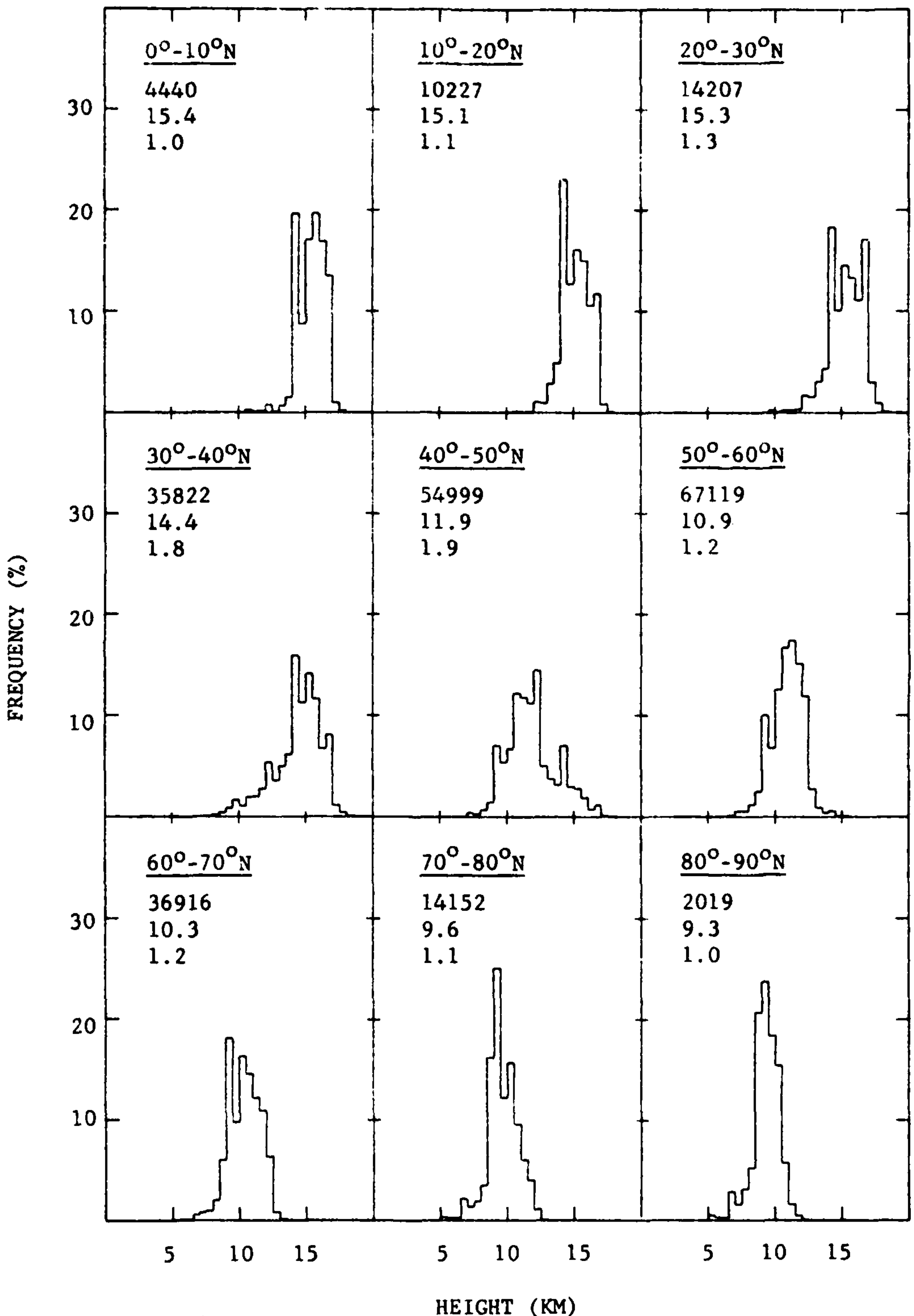


Figure 4h.

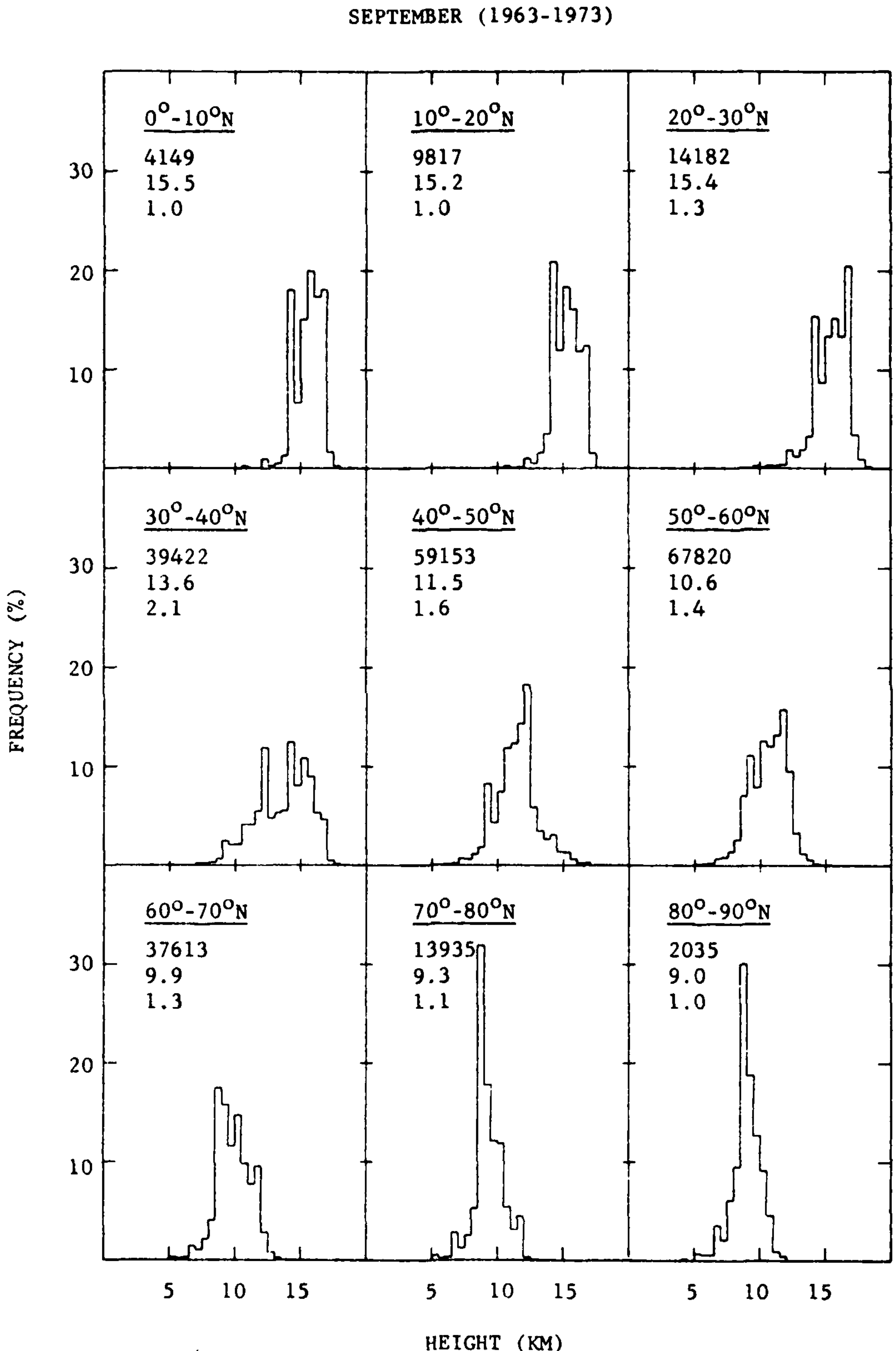

SEPTEMBER (1963-1973)
FREQUENCY (%)
HEIGHT (KM)
0°-10°N
4149
15.5
1.0
10°-20°N
9817
15.2
1.0
20°-30°N
14182
15.4
1.3
30°-40°N
39422
13.6
2.1
40°-50°N
59153
11.5
1.6
50°-60°N
67820
10.6
1.4
60°-70°N
37613
9.9
1.3
70°-80°N
13935
9.3
1.1
80°-90°N
2035
9.0
1.0
30
20
10
5
10
15

Figure 4i.

OCTOBER (1963-1973)

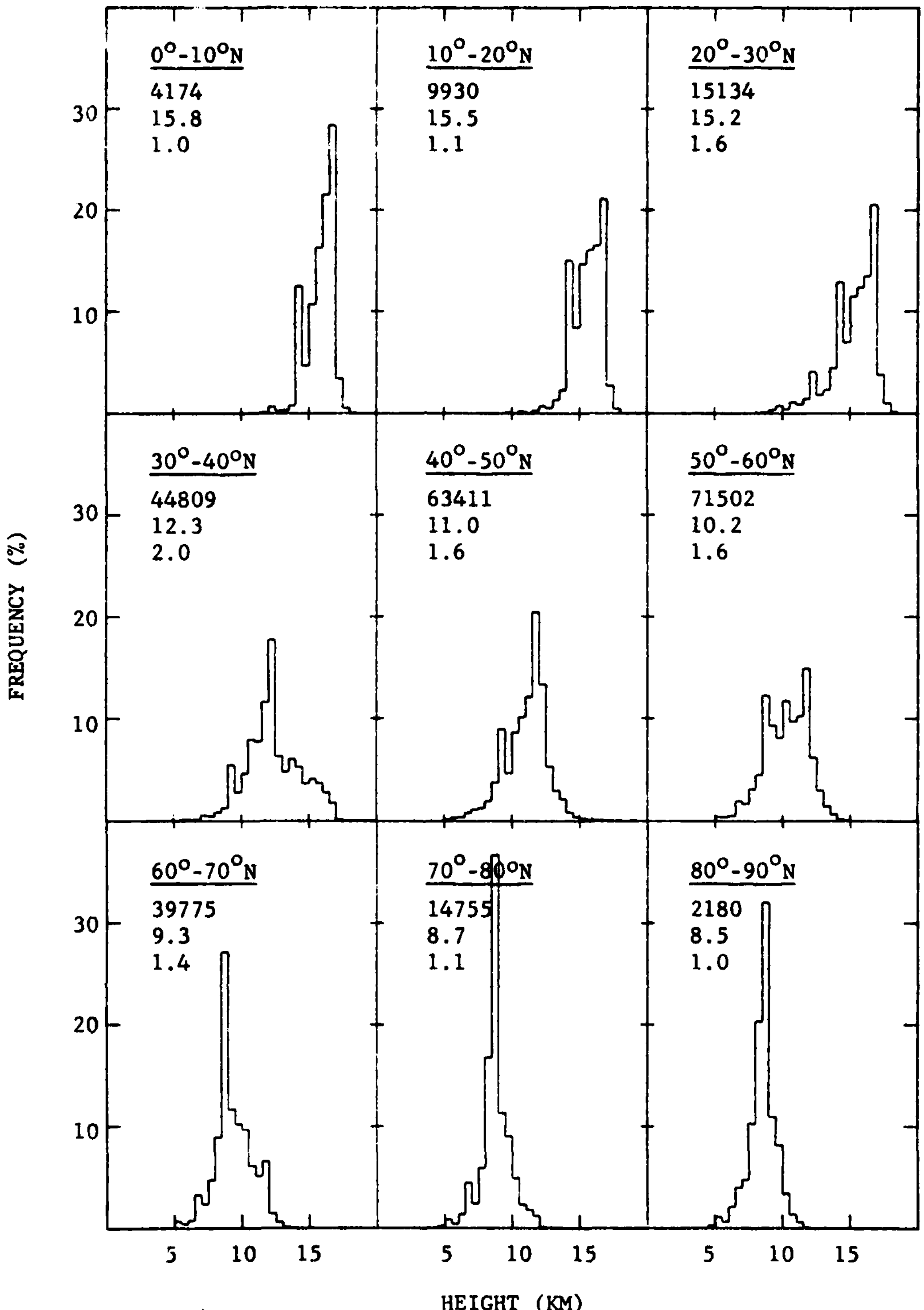


Figure 4j.

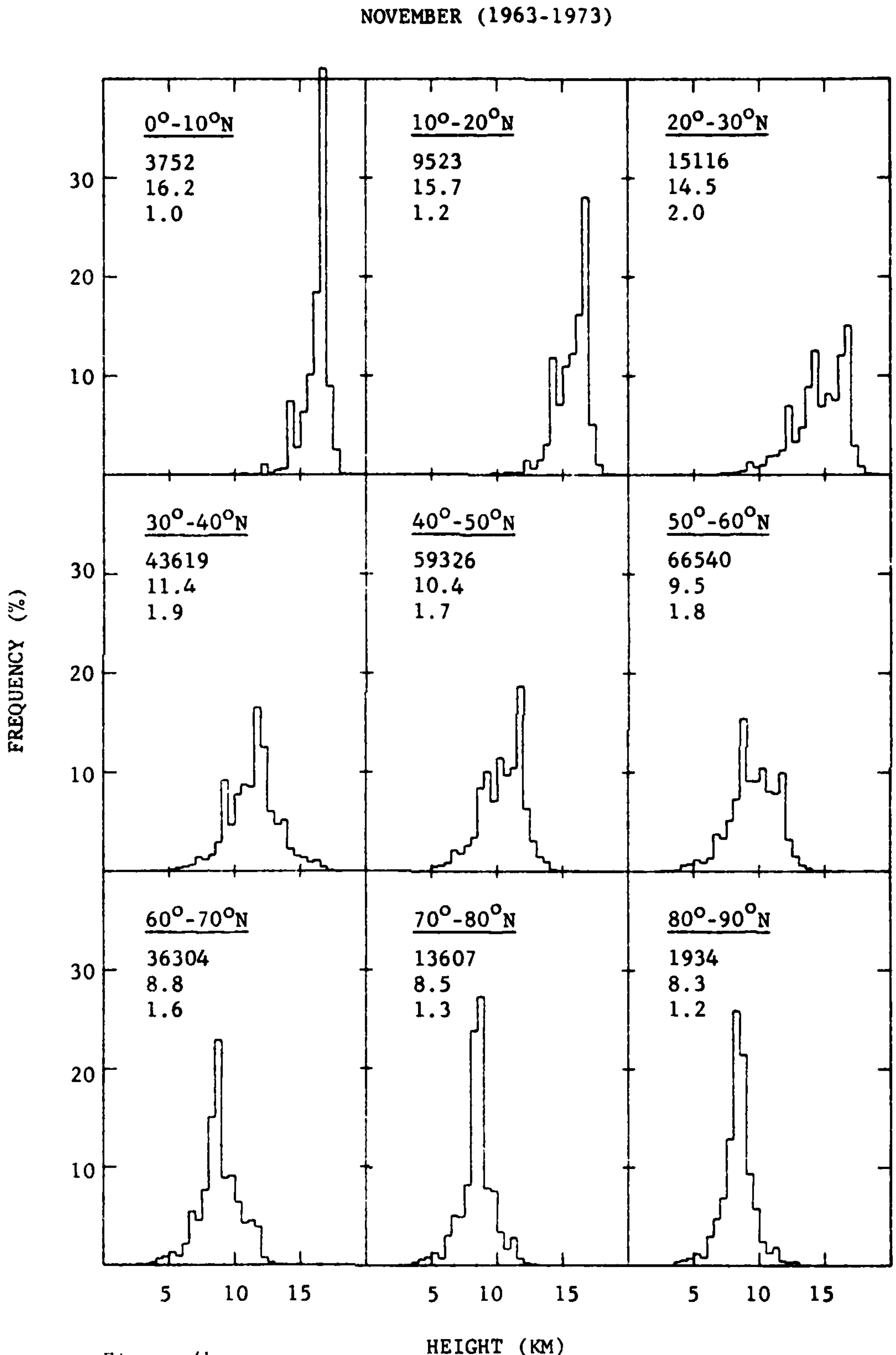

NOVEMBER (1963-1973)
0°-10°N
3752
16.2
1.0
10°-20°N
9523
15.7
1.2
20°-30°N
15116
14.5
2.0
30°-40°N
43619
11.4
1.9
40°-50°N
59326
10.4
1.7
50°-60°N
66540
9.5
1.8
60°-70°N
36304
8.8
1.6
70°-80°N
13607
8.5
1.3
80°-90°N
1934
8.3
1.2
FREQUENCY (%)
30
20
10
5
10
15
HEIGHT (KM)

Figure 4k.

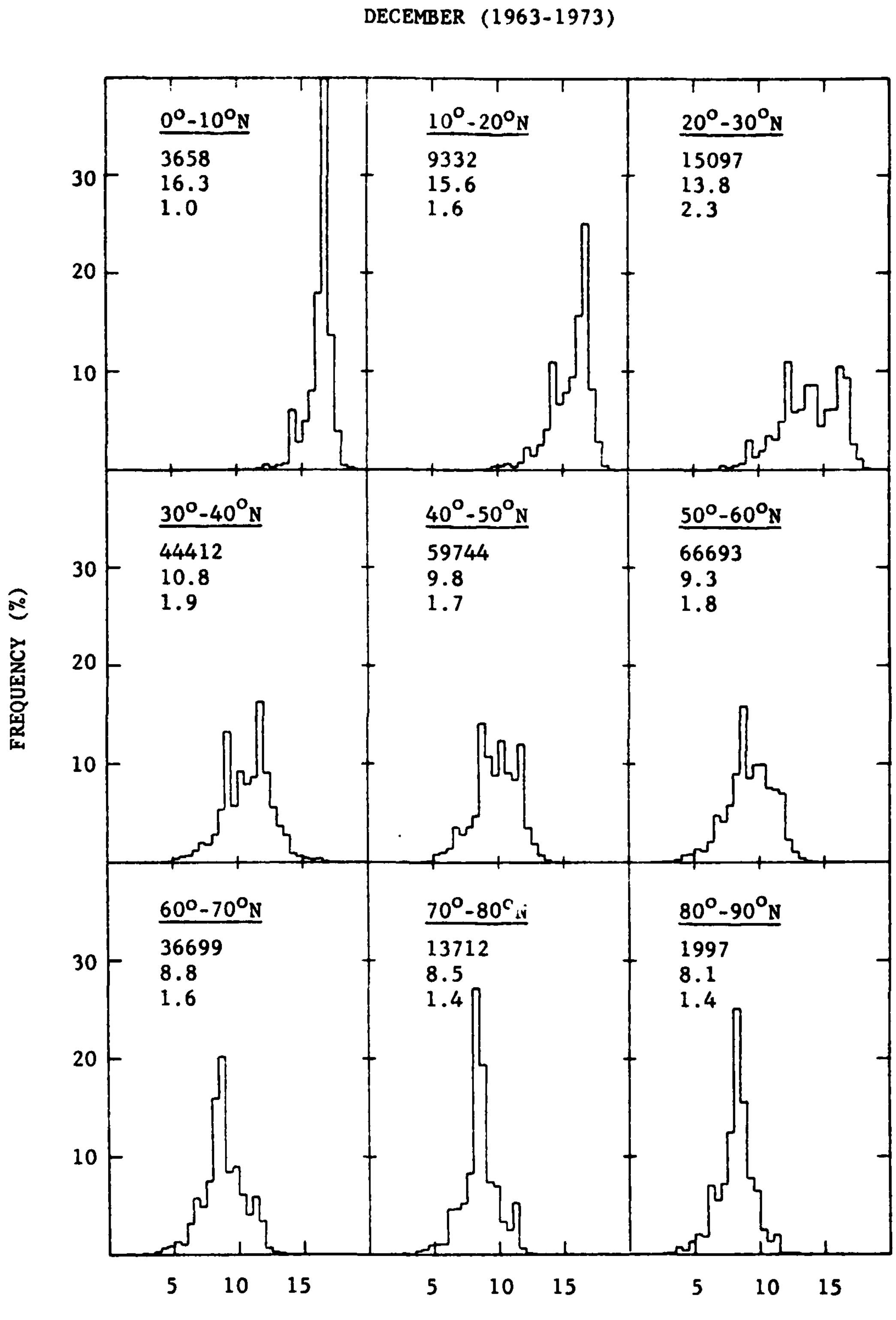

DECEMBER (1963-1973)
0°-10°N
3658
16.3
1.0
10°-20°N
9332
15.6
1.6
20°-30°N
15097
13.8
2.3
30°-40°N
44412
10.8
1.9
40°-50°N
59744
9.8
1.7
50°-60°N
66693
9.3
1.8
60°-70°N
36699
8.8
1.6
70°-80°N
13712
8.5
1.4
80°-90°N
1997
8.1
1.4
FREQUENCY (%)
10
20
30
5
10
15
HEIGHT (KM)

Figure 41.

JANUARY (1964-1973)

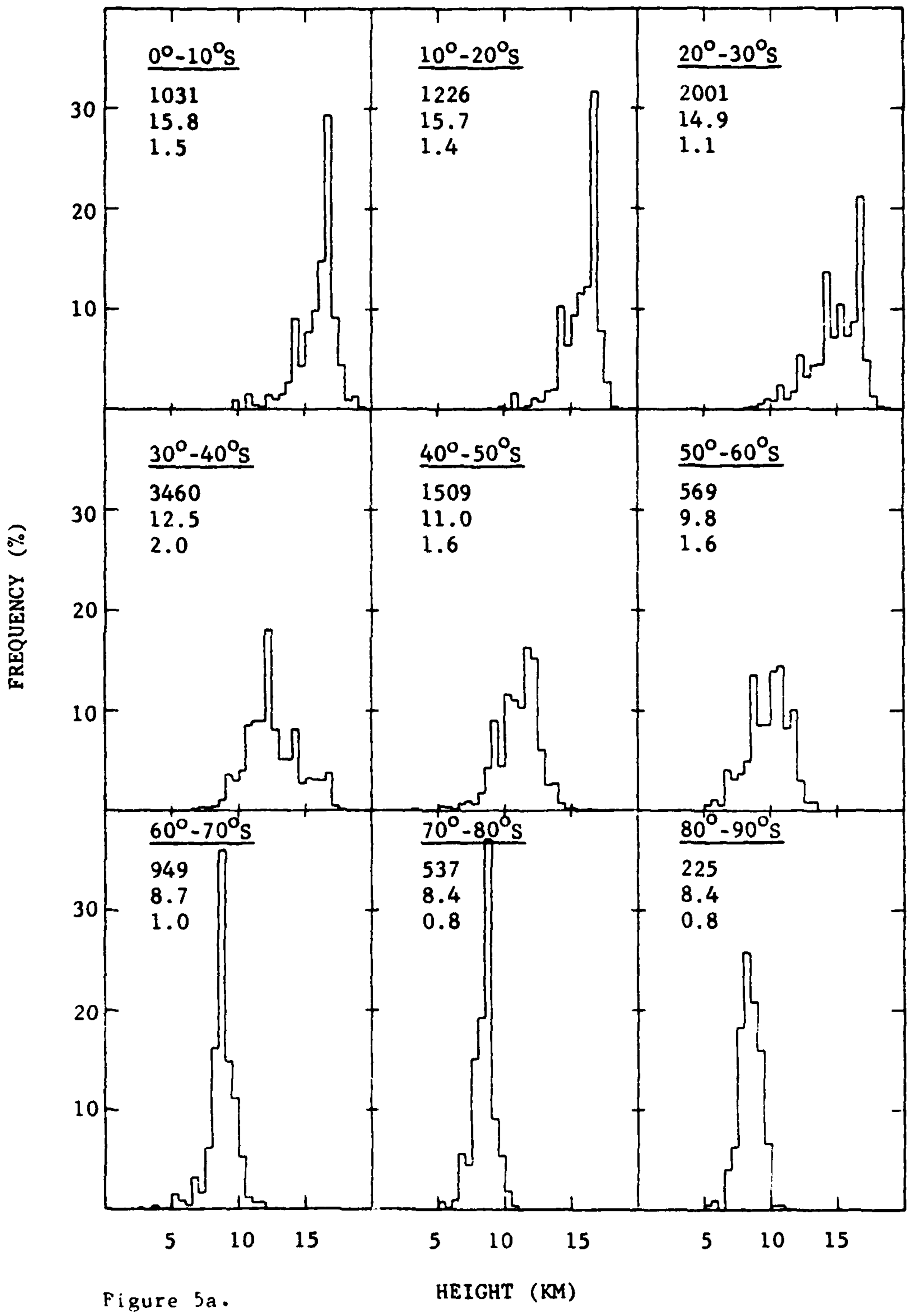


Figure 5a.

FEBRUARY (1964-1973)

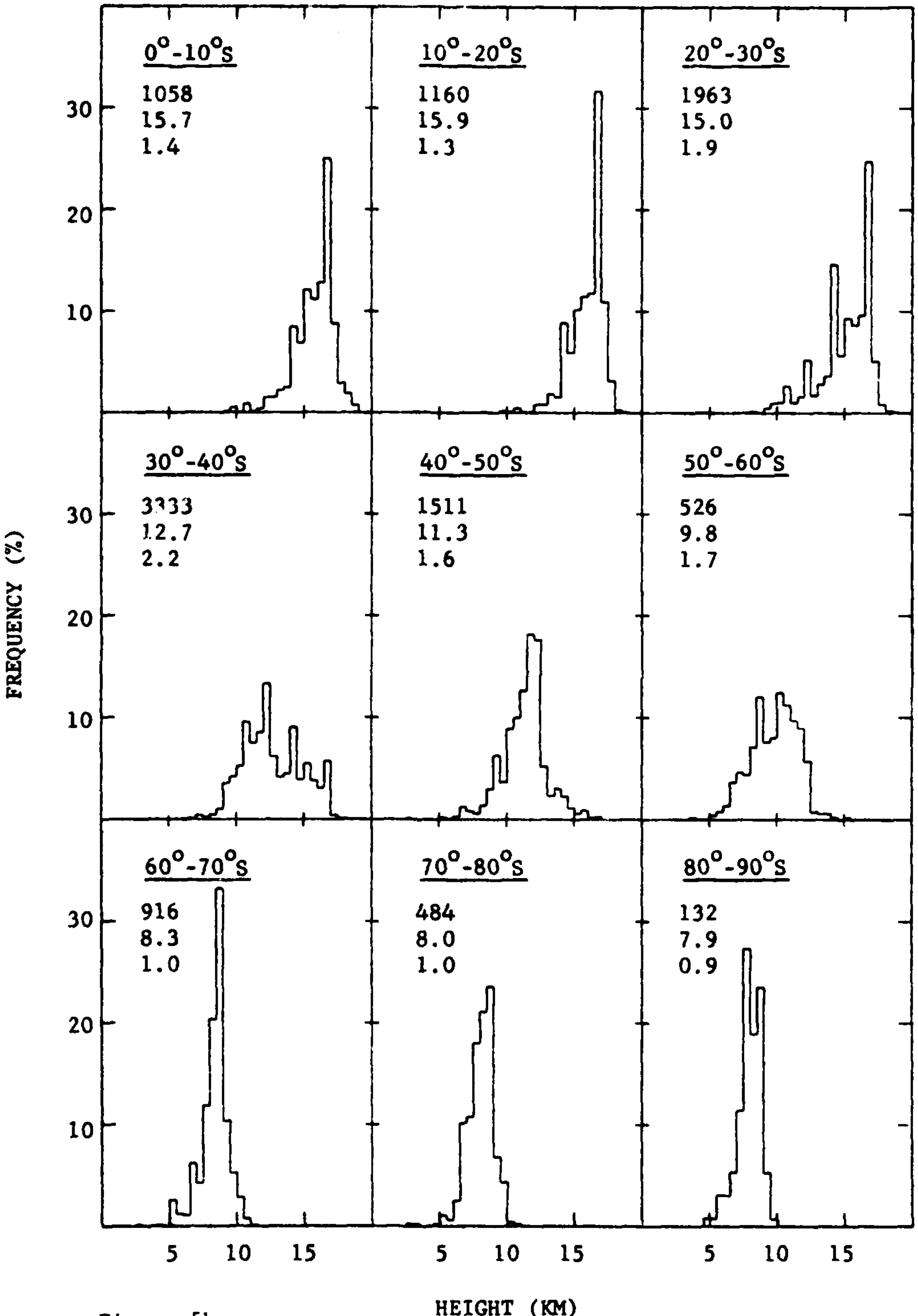


Figure 5b.

MARCH (1964-1973)

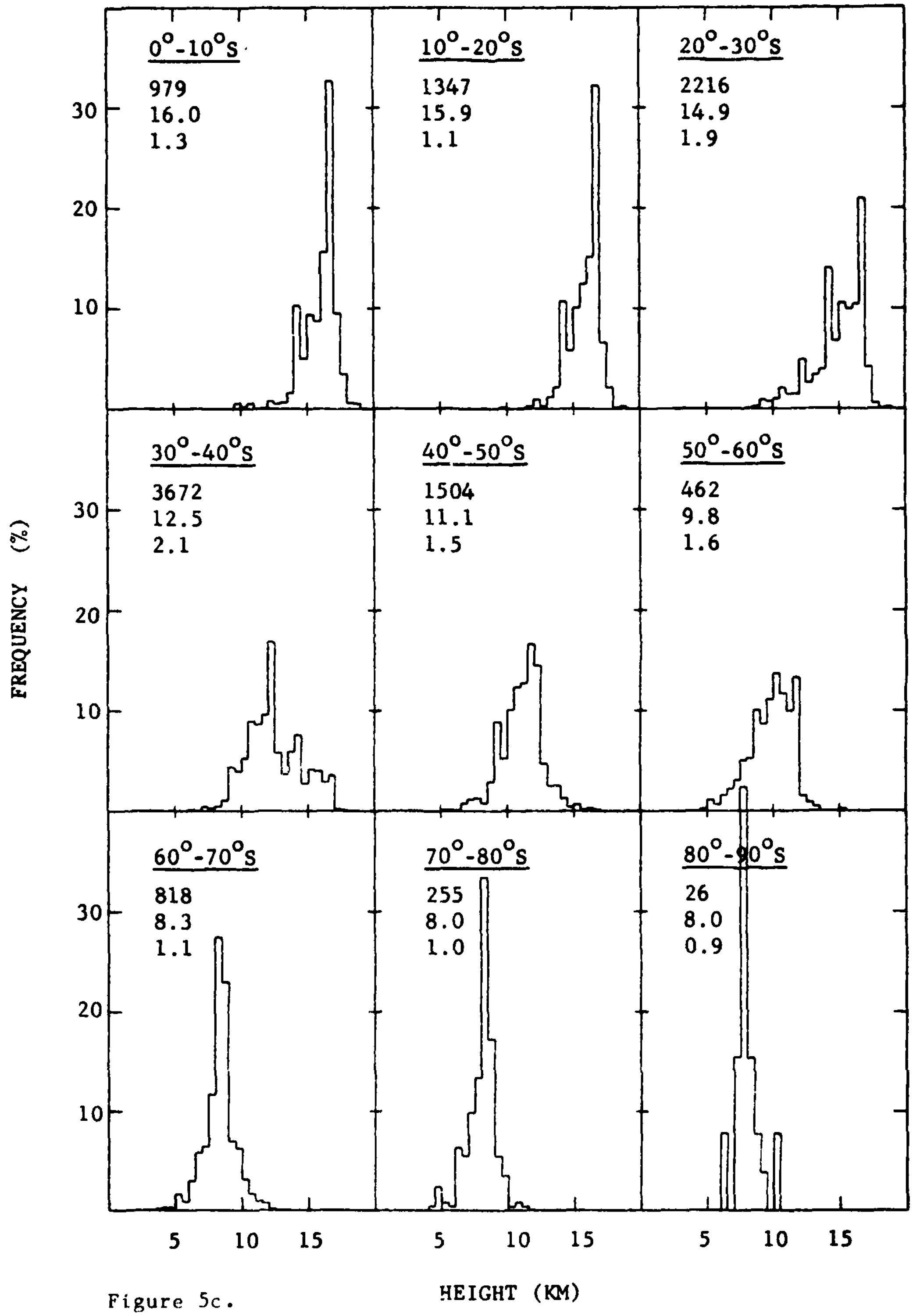


Figure 5c.

APRIL (1964-1973)

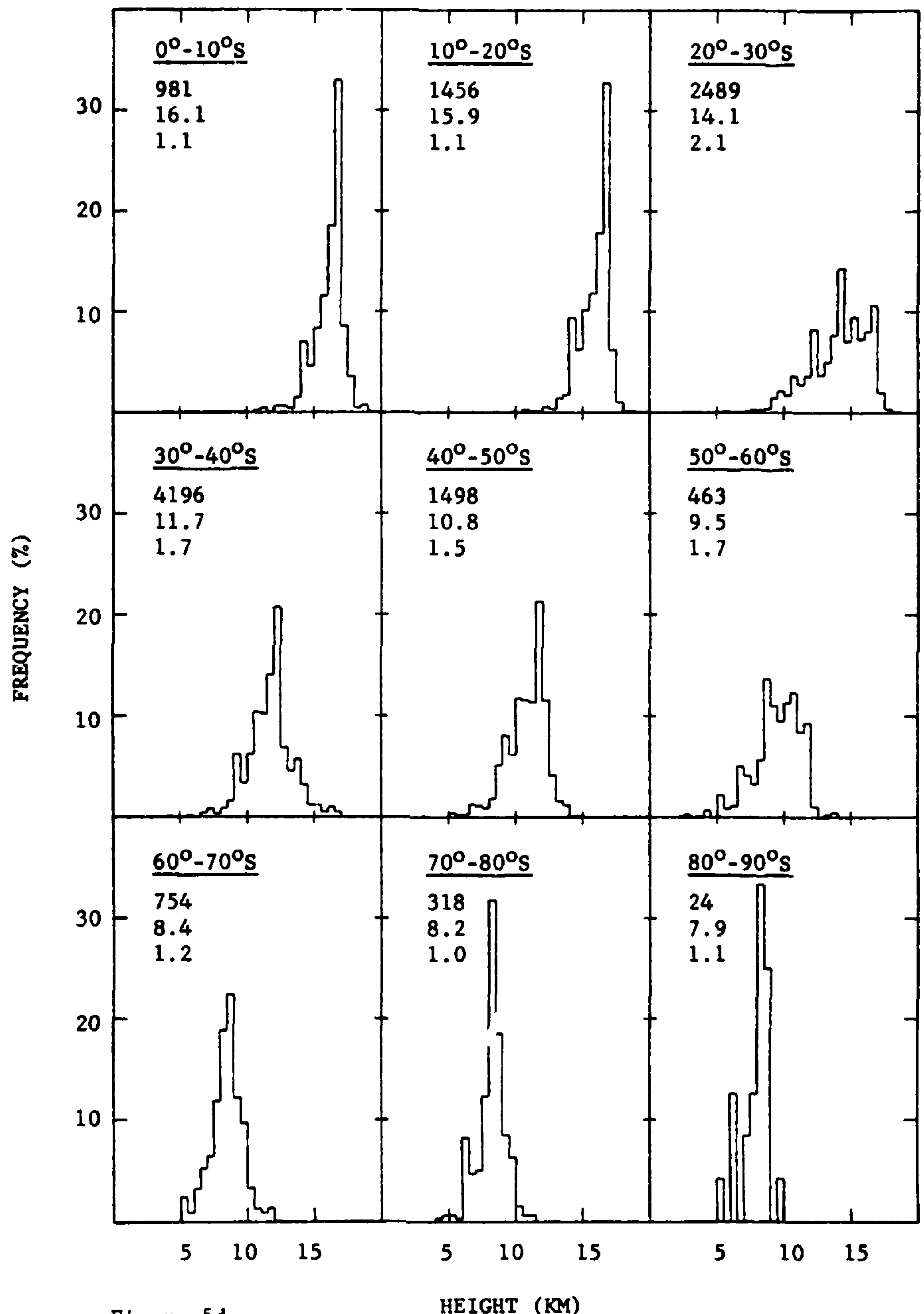


Figure 5d.

MAY (1964-1973)

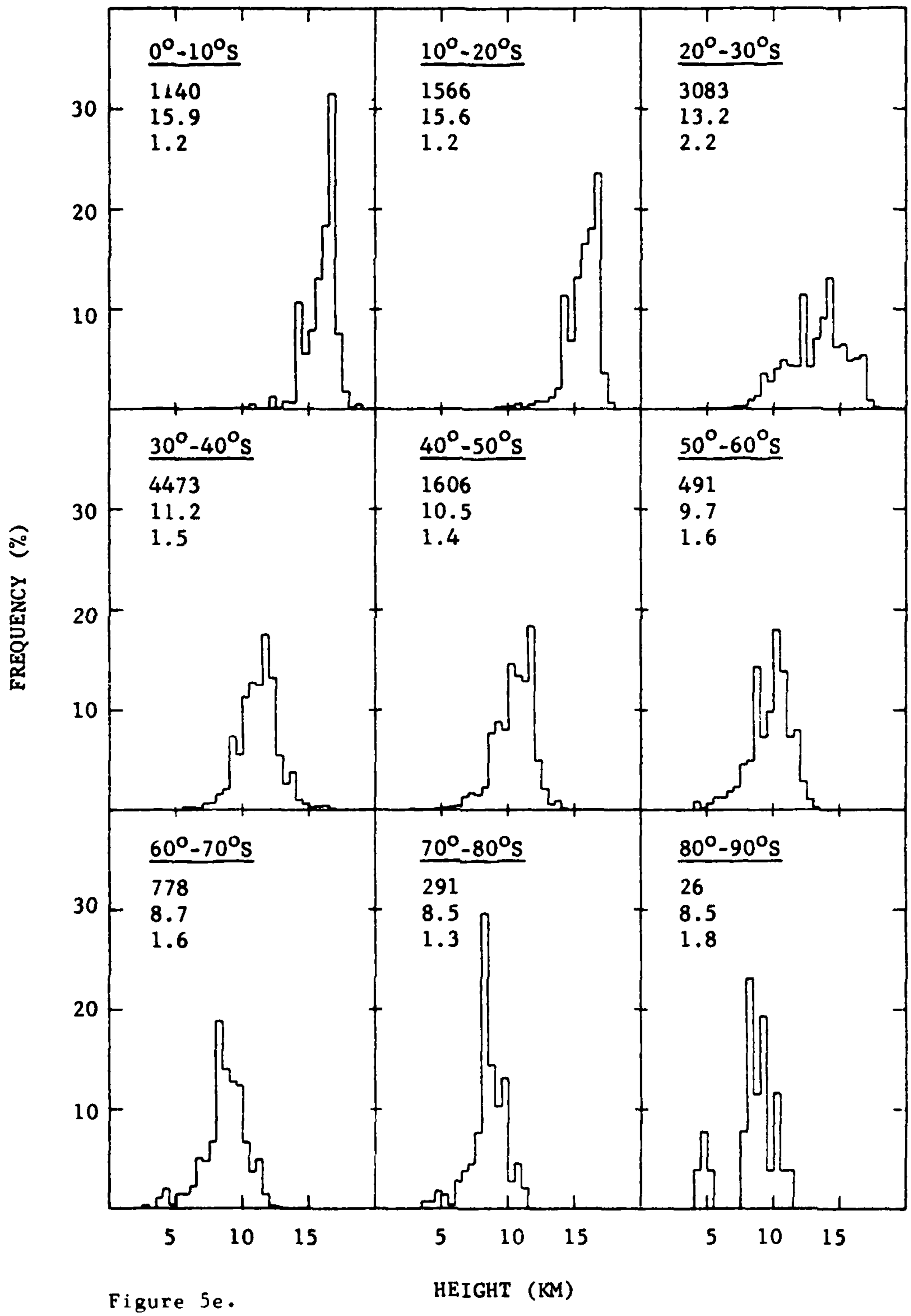


Figure 5e.

JUNE (1964-1973)

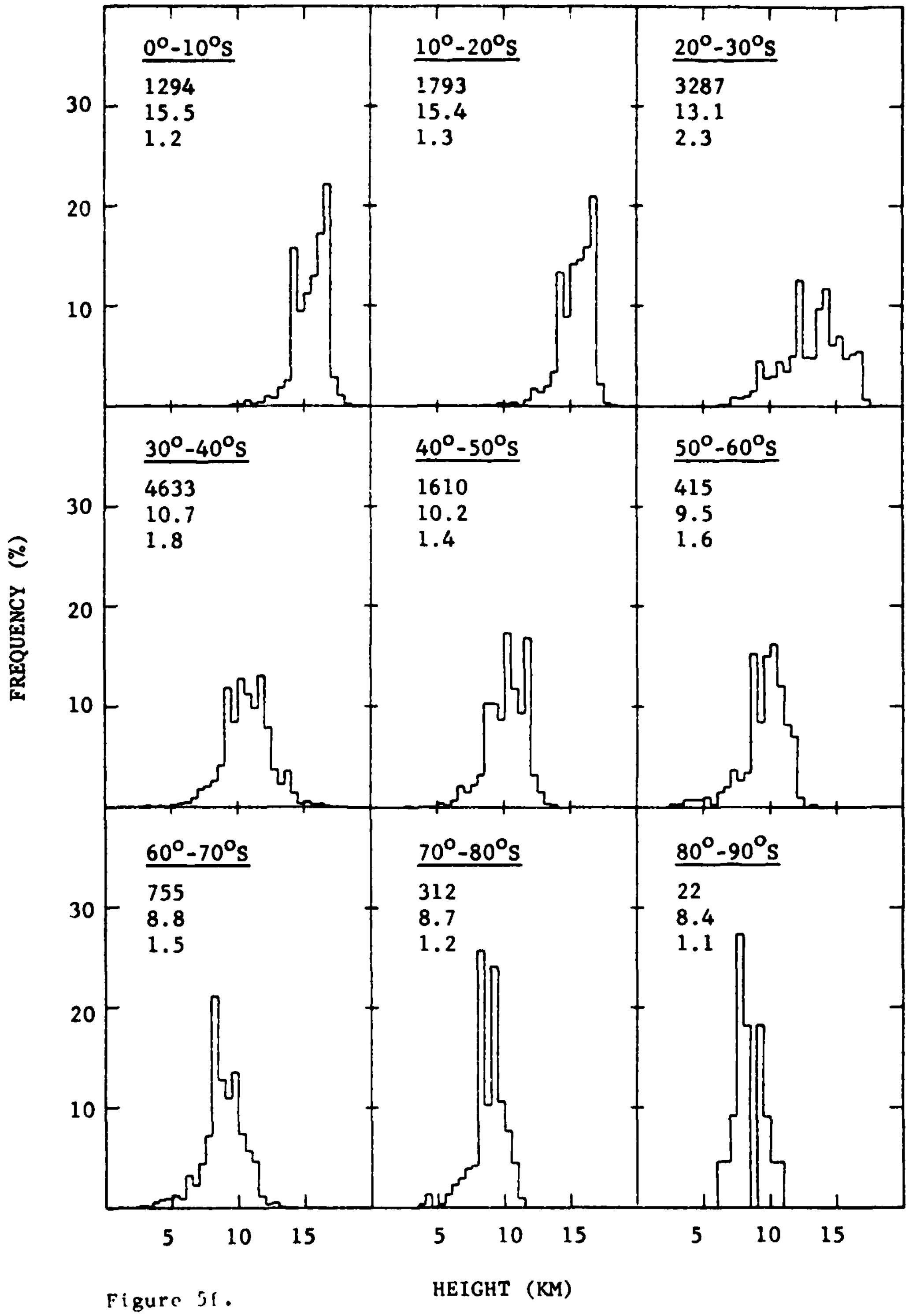


Figure 5f.

JULY (1964-1973)

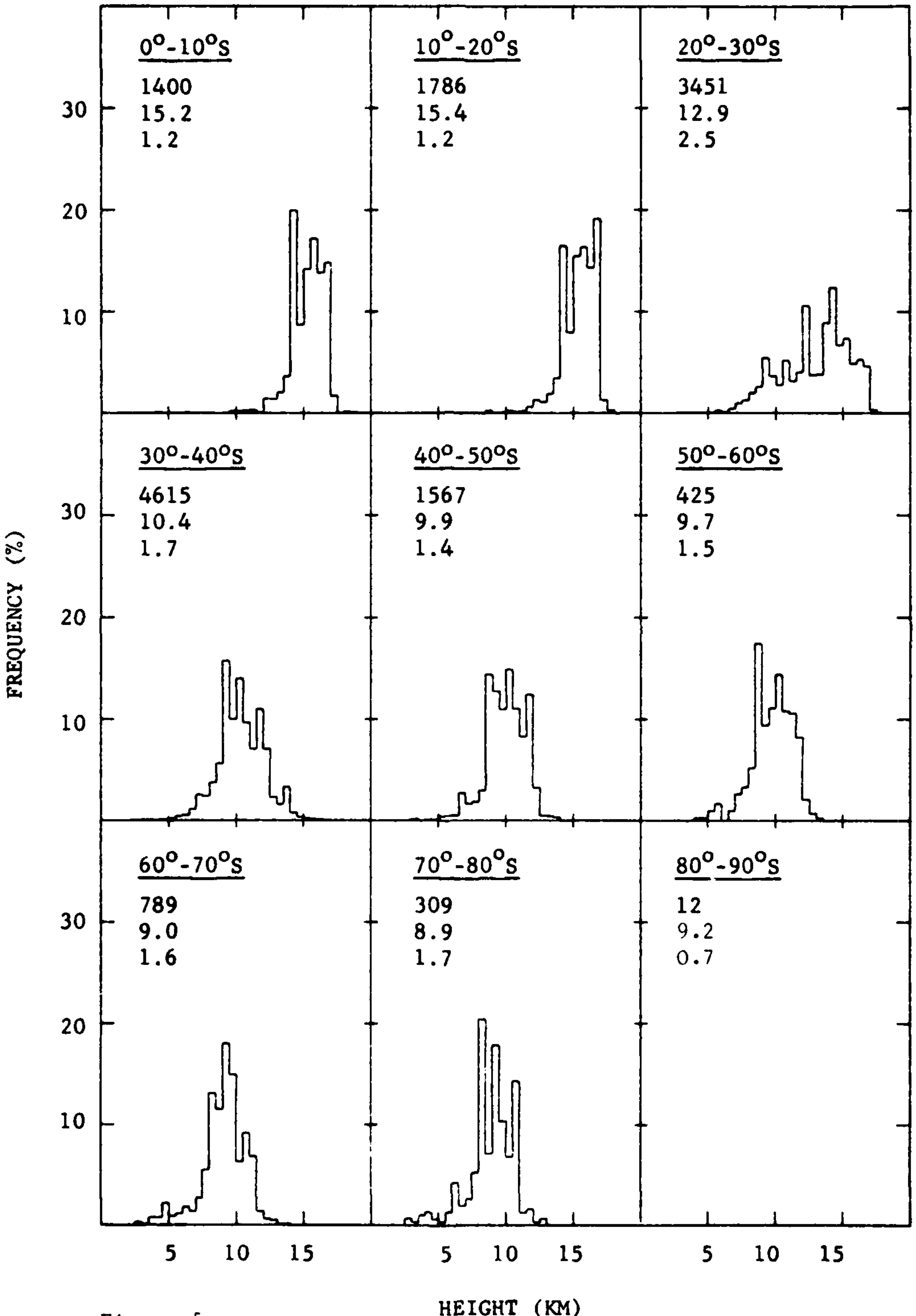


Figure 5g.

AUGUST (1964-1973)

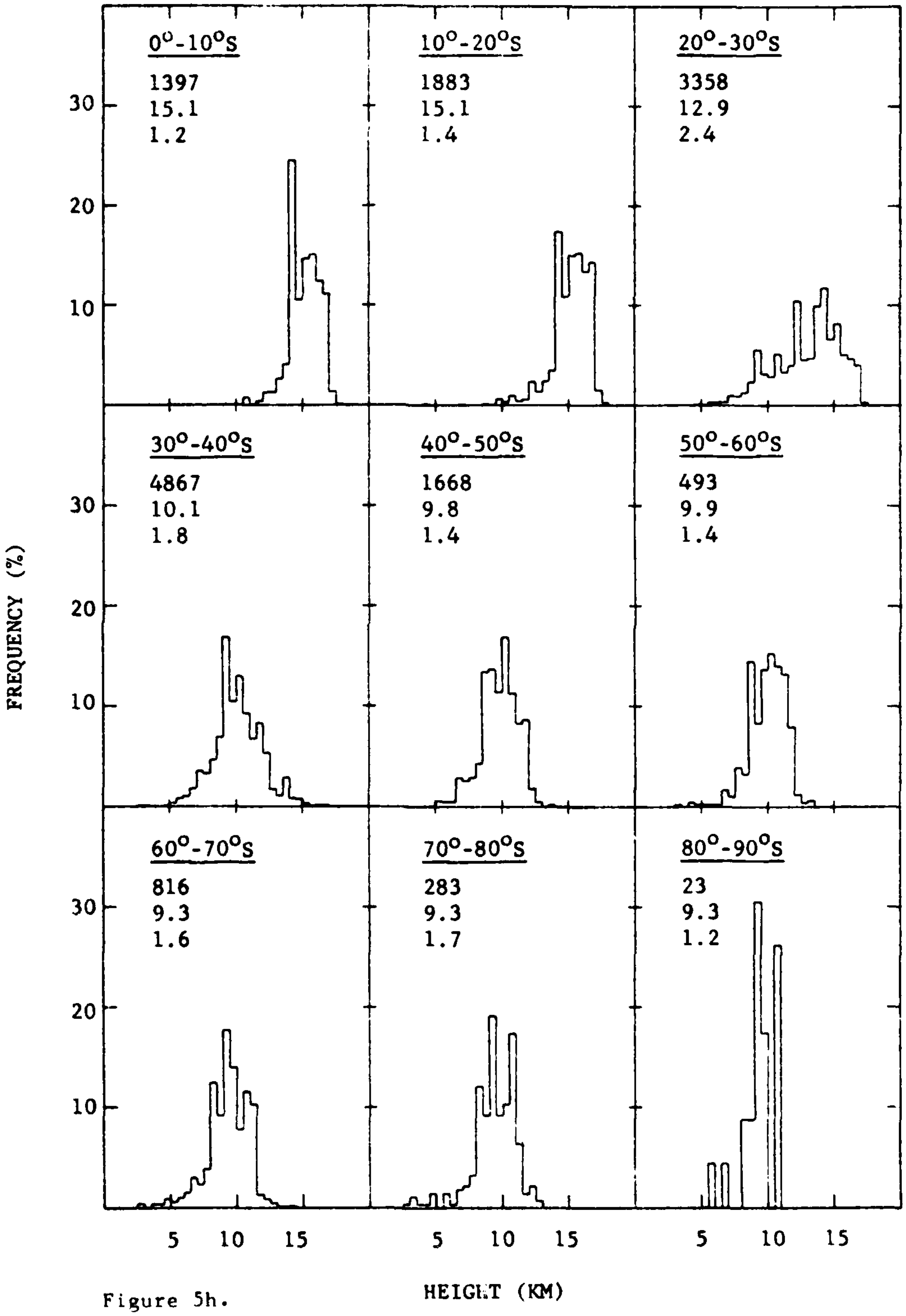


Figure 5h.

AD-A106 399 CONTROL DATA CORP MINNEAPOLIS MINN RESEARCH DIV F/G 4/2
A CLIMATOLOGY OF A NEWLY-DEFINED TROPOPAUSE USING SIMULTANEOUS --ETC(U)
MAY 81 J M ROE F19628-79-C-0098
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SEPTEMBER (1963-1973)

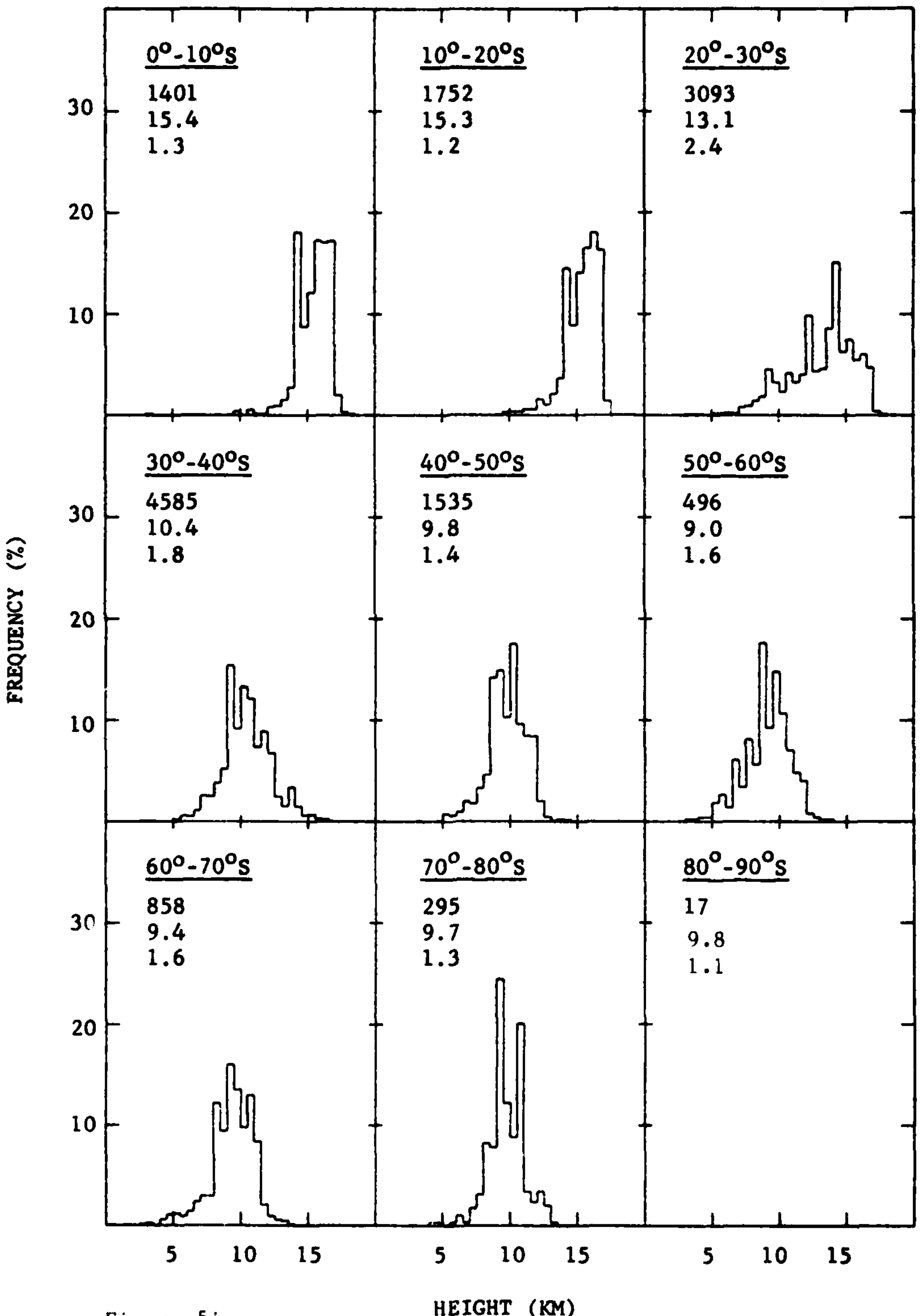

Figure 5i.

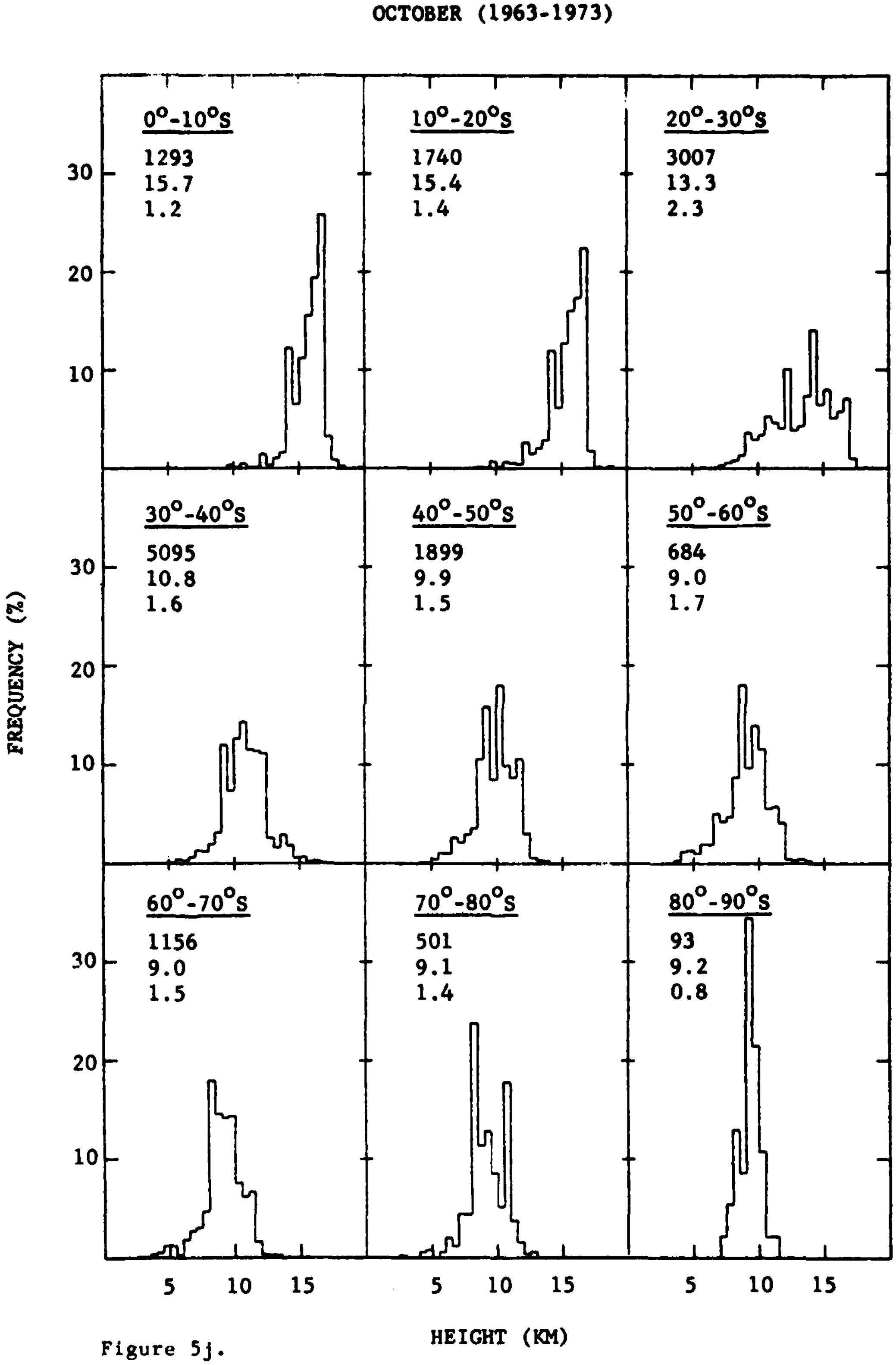
OCTOBER (1963-1973)
0°-10°S
1293
15.7
1.2
10°-20°S
1740
15.4
1.4
20°-30°S
3007
13.3
2.3
30°-40°S
5095
10.8
1.6
40°-50°S
1899
9.9
1.5
50°-60°S
684
9.0
1.7
60°-70°S
1156
9.0
1.5
70°-80°S
501
9.1
1.4
80°-90°S
93
9.2
0.8
FREQUENCY (%)
30
20
10
5
10
15
HEIGHT (KM)

Figure 5j.

NOVEMBER (1963-1973)

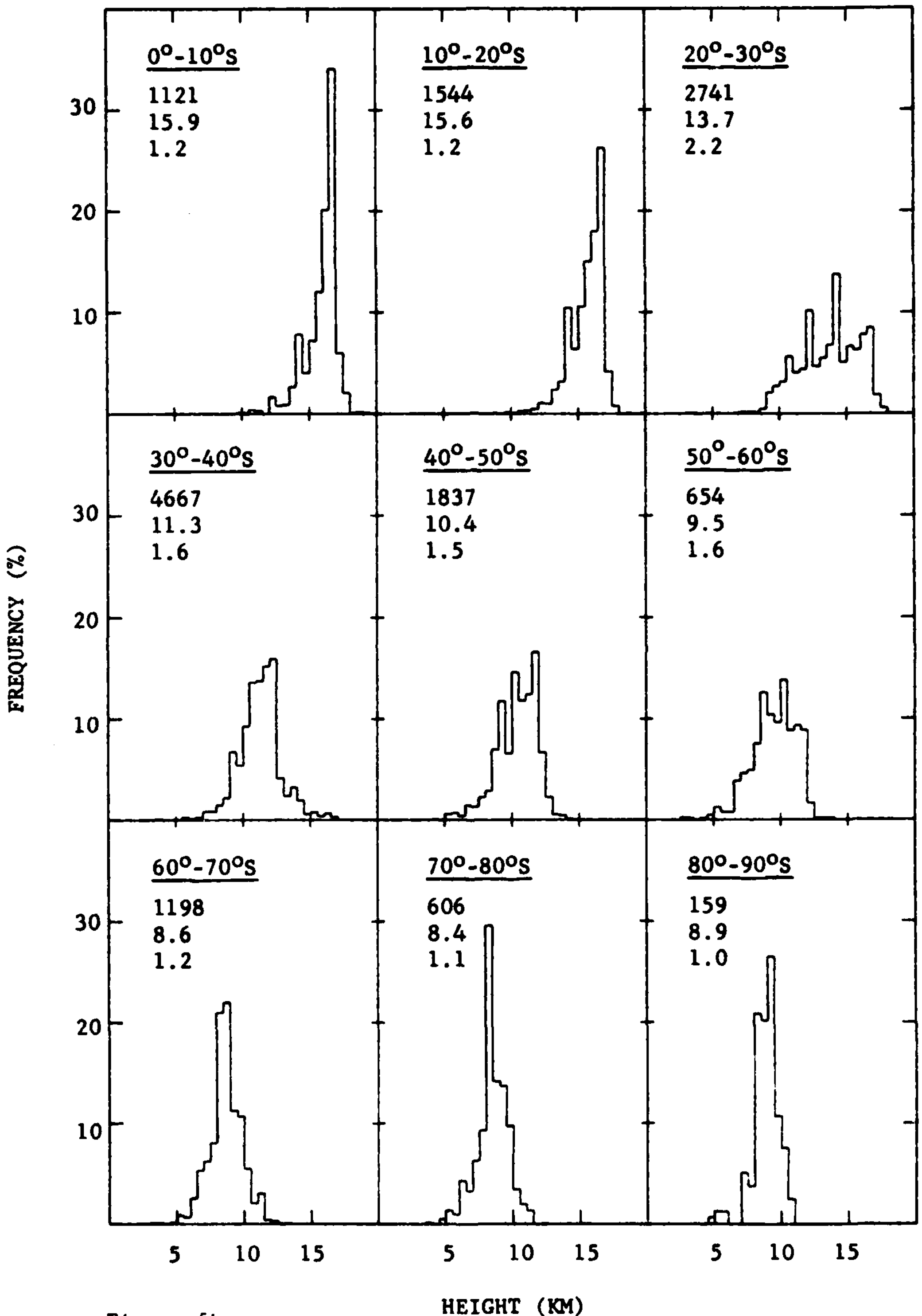

Figure 5k.

DECEMBER (1963-1973)

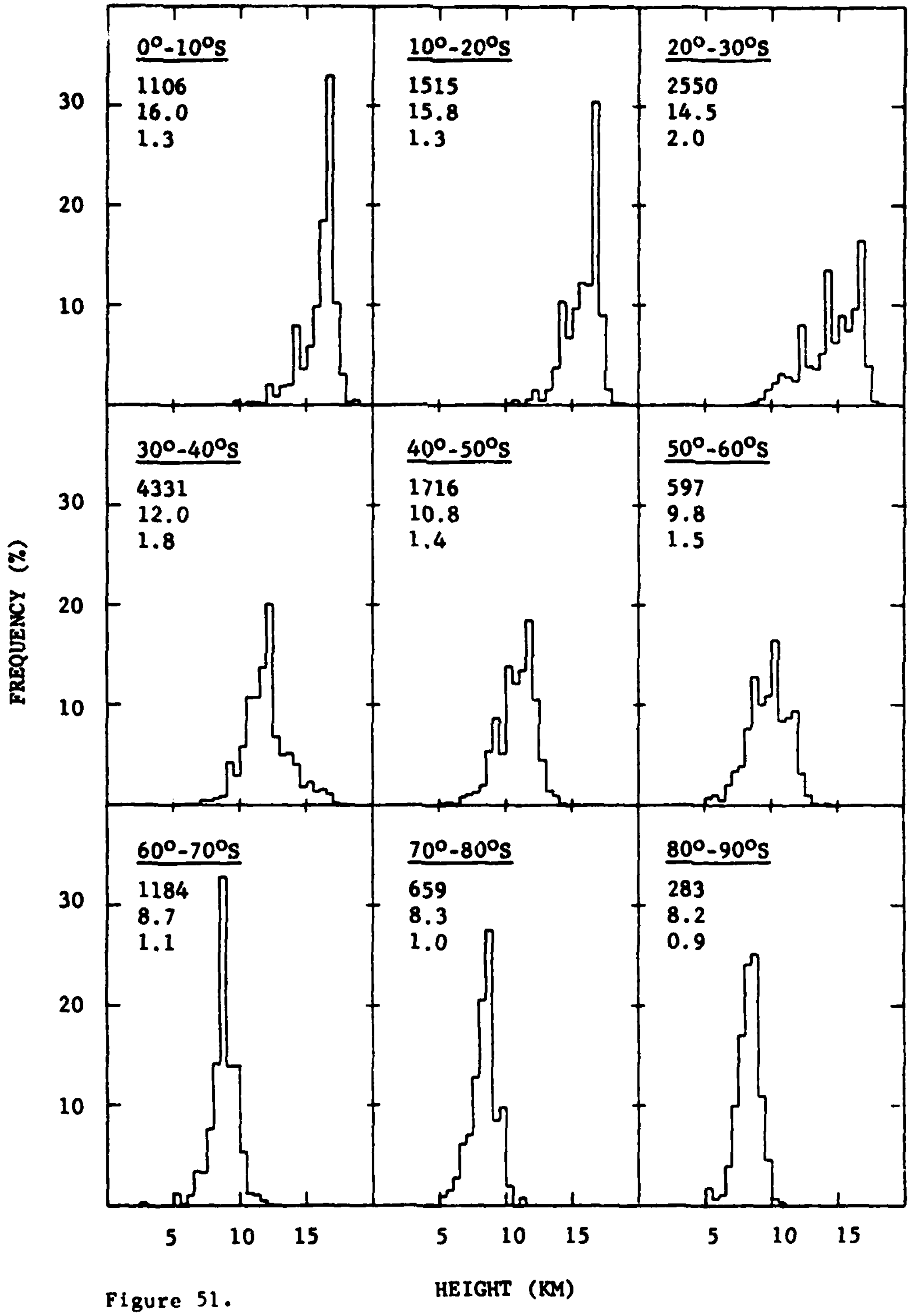

Figure 51.

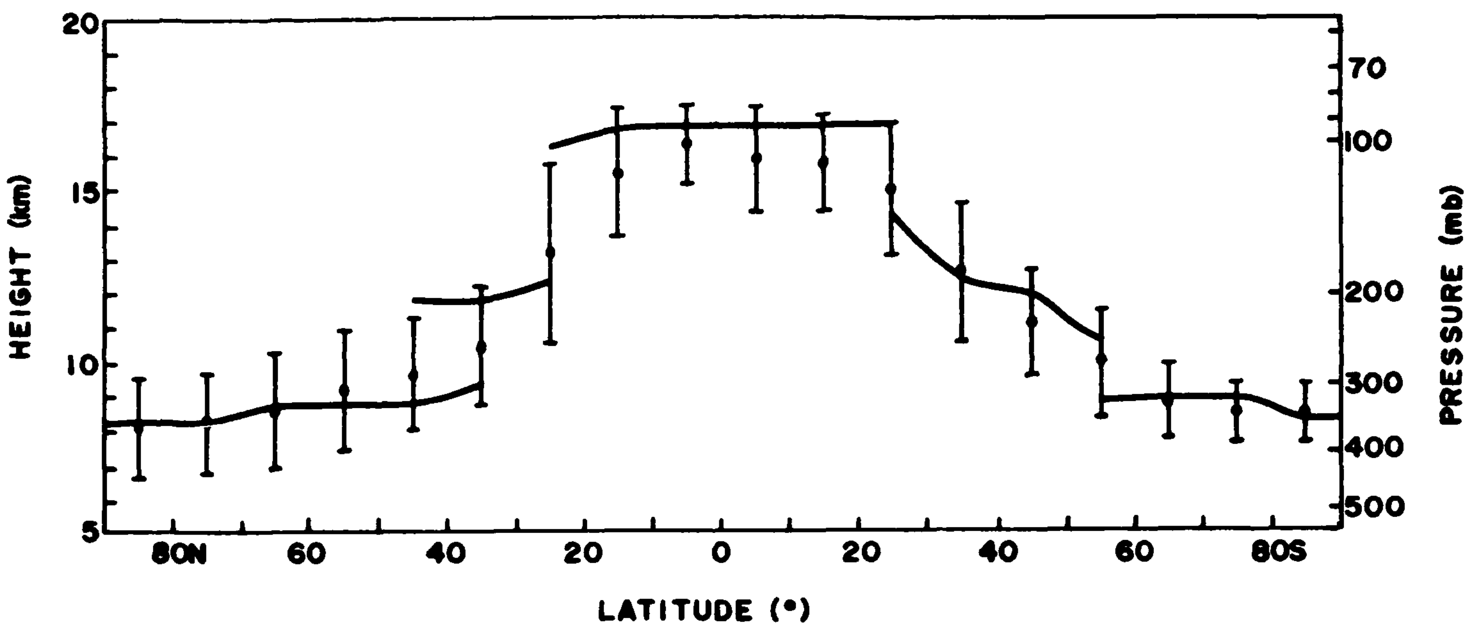

Figure 6a. Monthly height-latitude cross-section of the tropopause for January. Heavy dots with error bars are the long-term zonal mean tropopause height plus overall standard deviation. The solid lines are predominant modes of the frequency distributions extracted from Figures 4a-51. The U. S. Standard Atmosphere pressure scale is given at right.

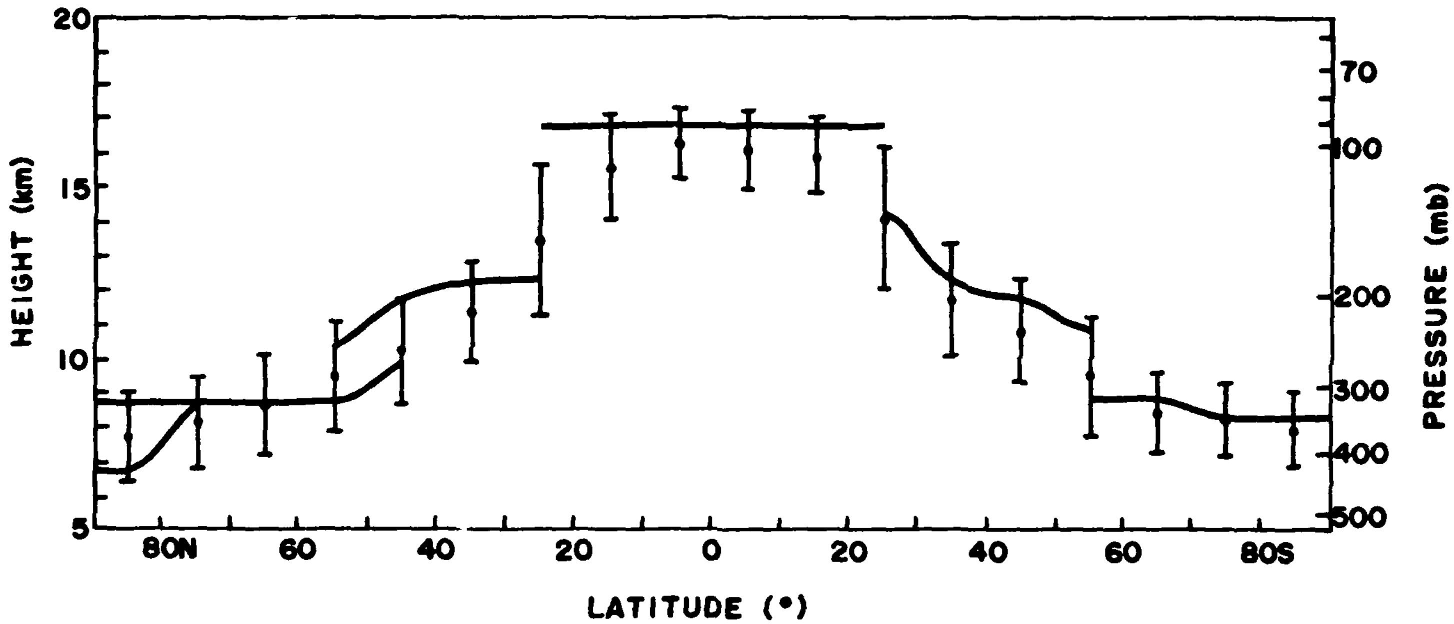

Figure 6b. Same as Figure 6a except for April.

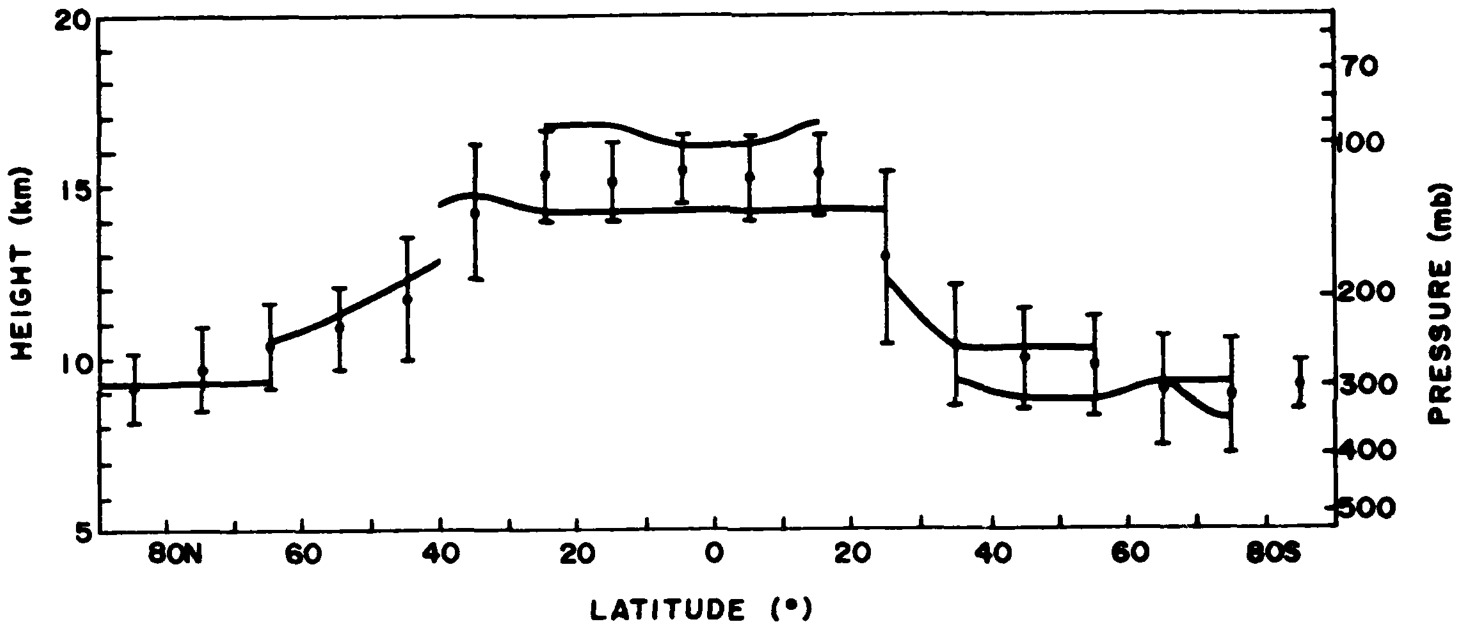

Figure 6c. Same as Figure 6a except for July.

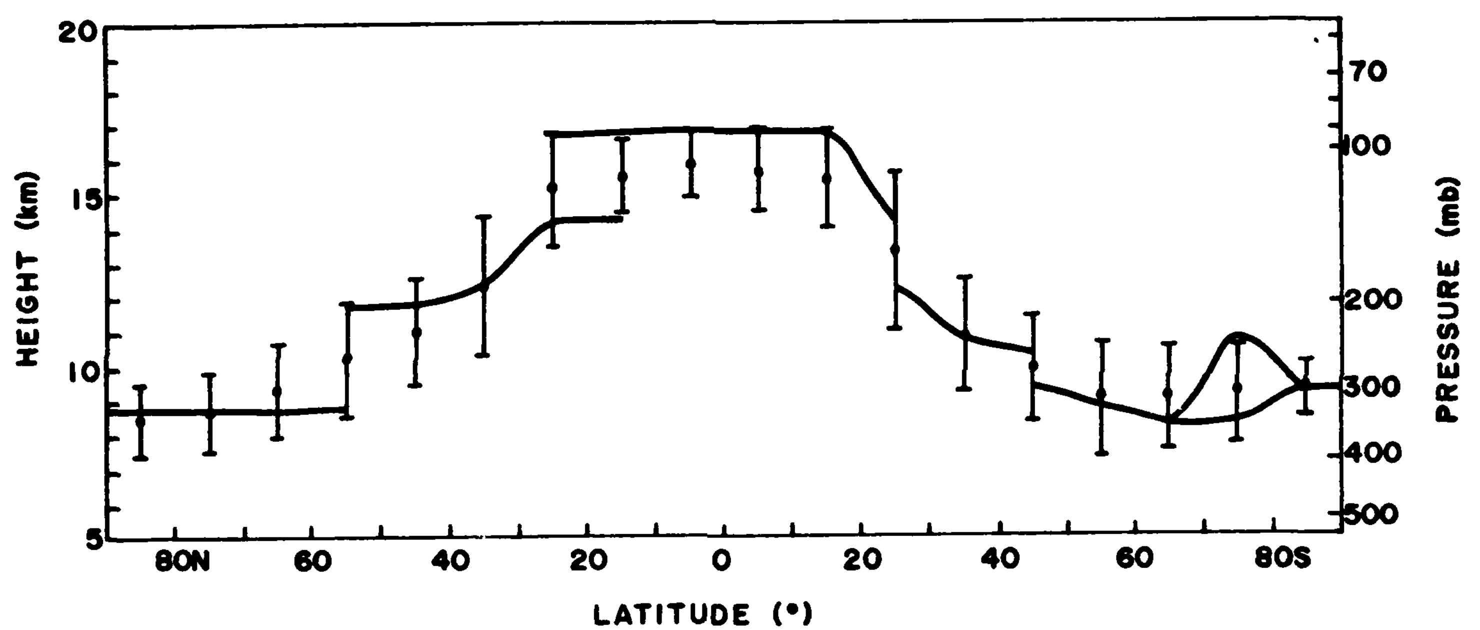

Figure 6d. Same as Figure 6a except for October.

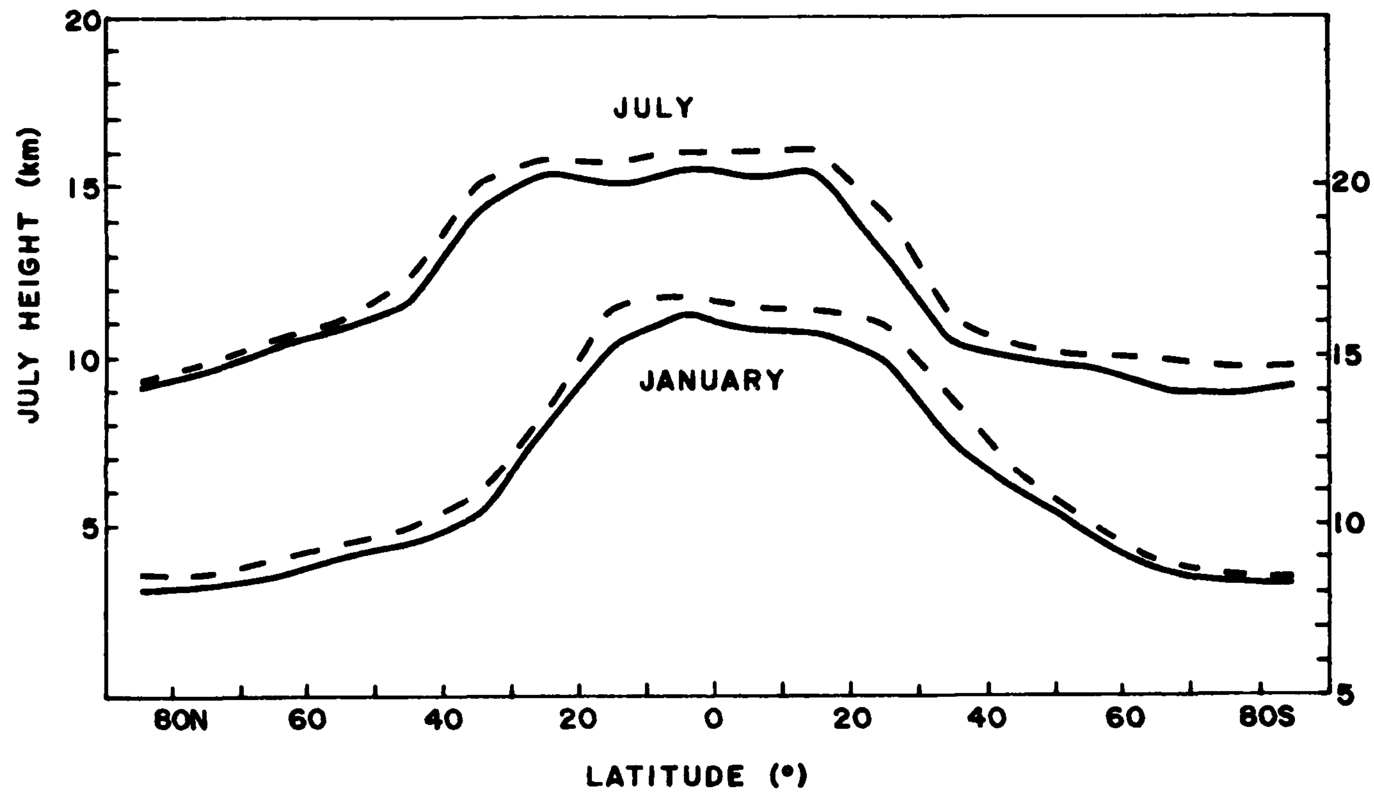

Figure 7. Height-latitude cross-sectional comparison of the long-term zonal mean tropopause height using the WMO definition (dashed lines) and the new definition (solid lines) for July and January.

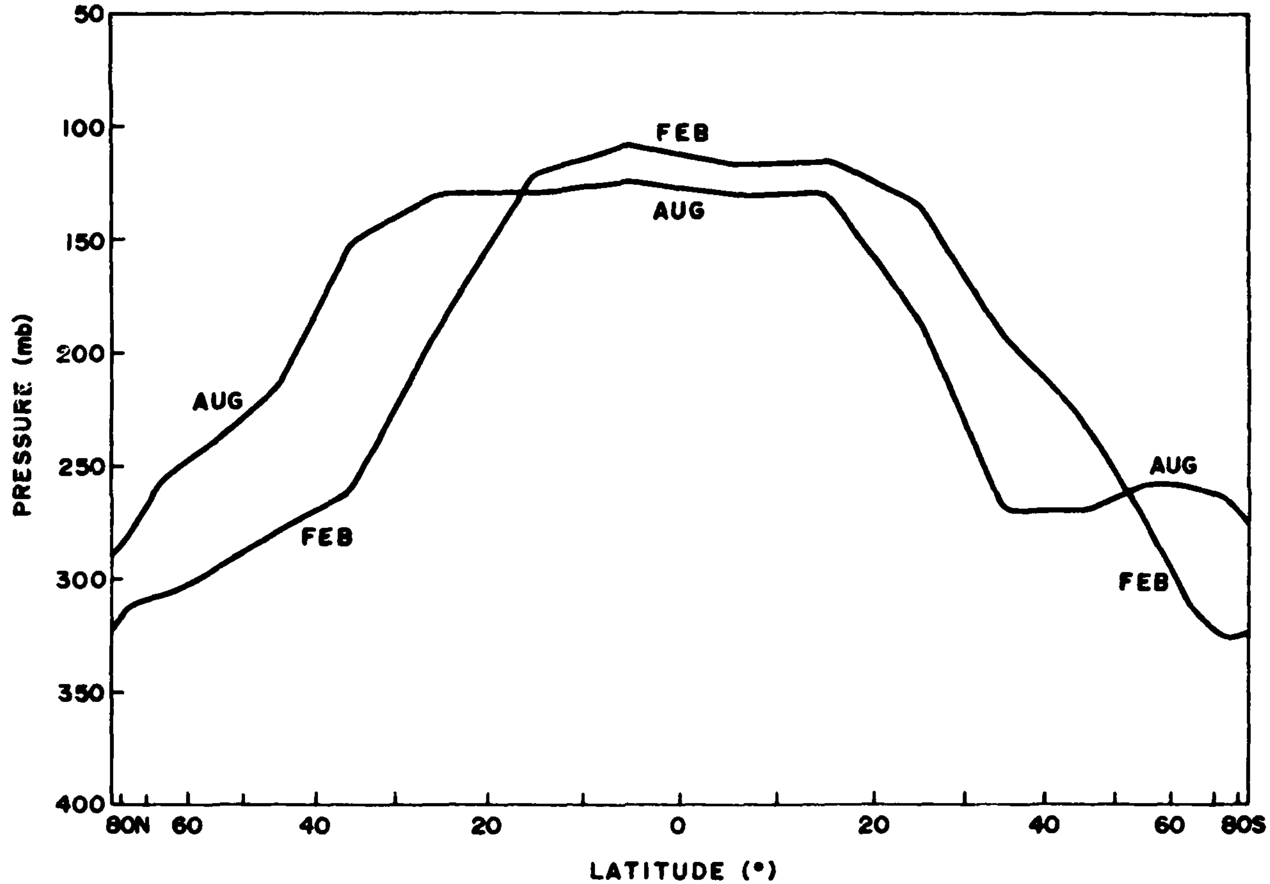

Figure 8. Pressure-latitude cross-section of the long-term monthly mean tropopause for February and August depicting the seasonal variation of stratospheric mass. Long-term means are equally weighted by year. Area in figure is proportional to mass.

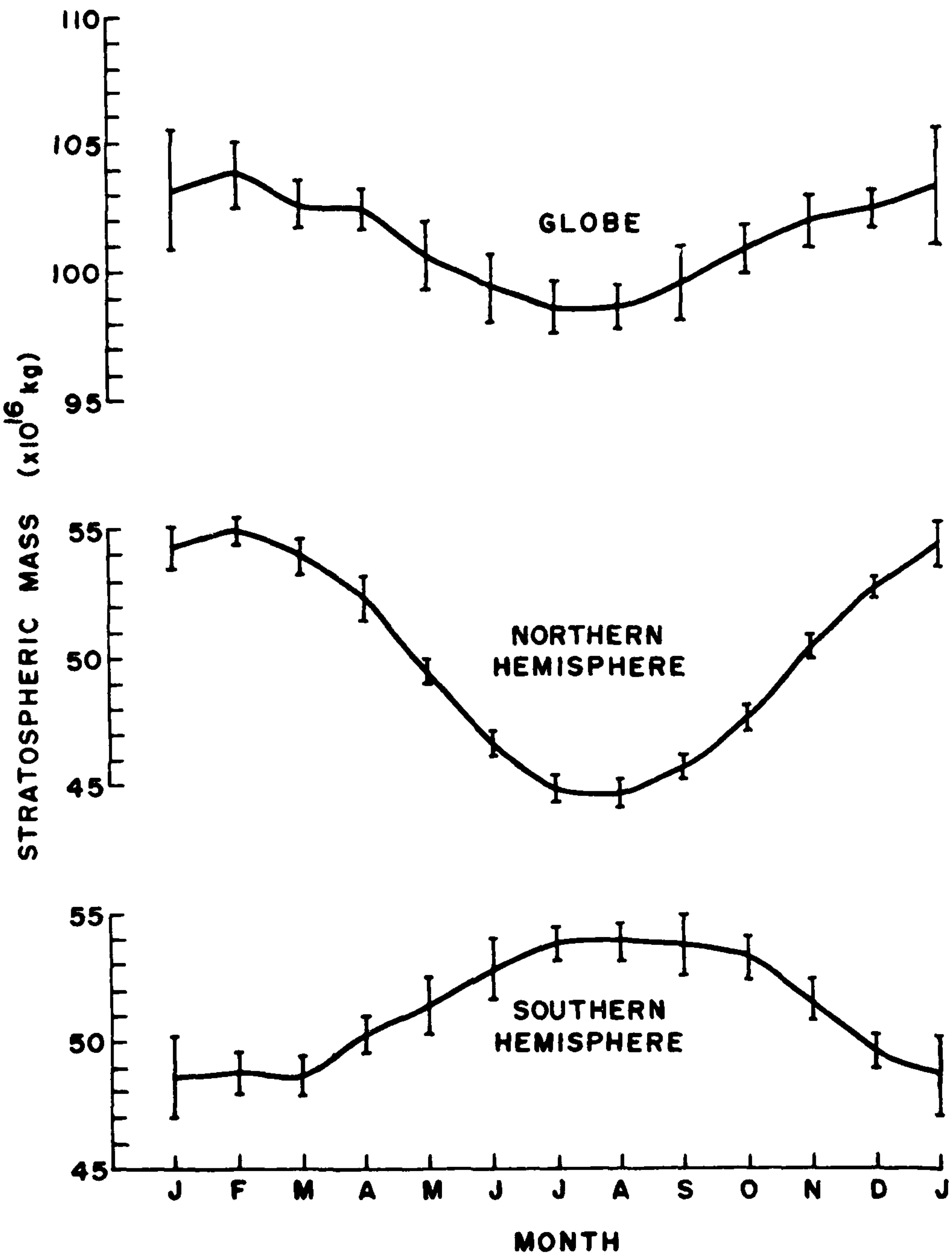

Figure 9. Long-term seasonal change of stratospheric mass for each hemisphere and the entire globe. Long-term means are equally weighted by year using 10 or 11 years for the Northern Hemisphere and 7 years for the Southern Hemisphere plus globe (see text). Error bars are the interannual standard deviations.

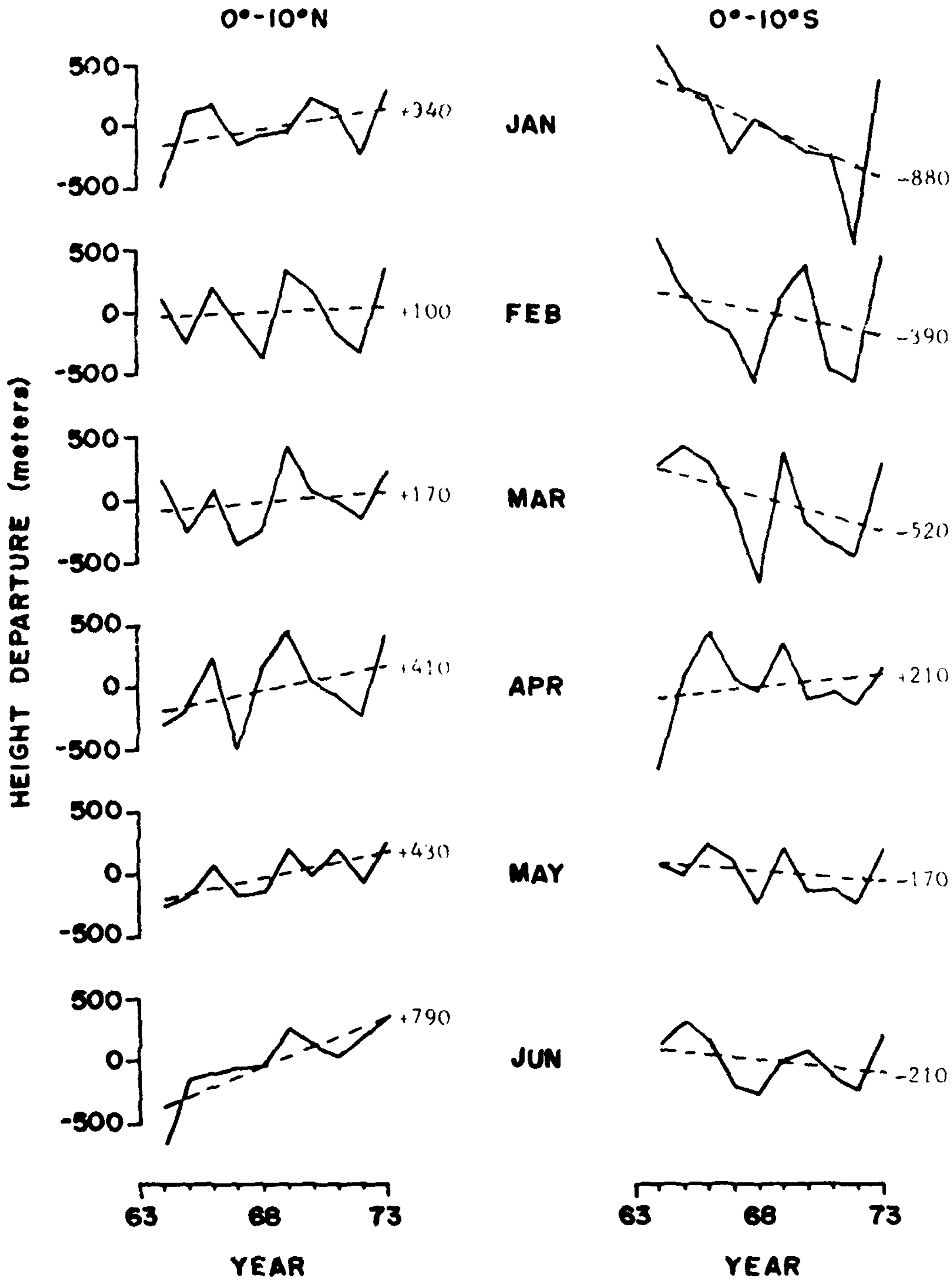

Figure 10a. Tropopause height departures from long-term monthly means for the tropics from January to June (solid lines). The long-term trend is given by the best fit lines (dashed) and expressed as meters per decade at right.

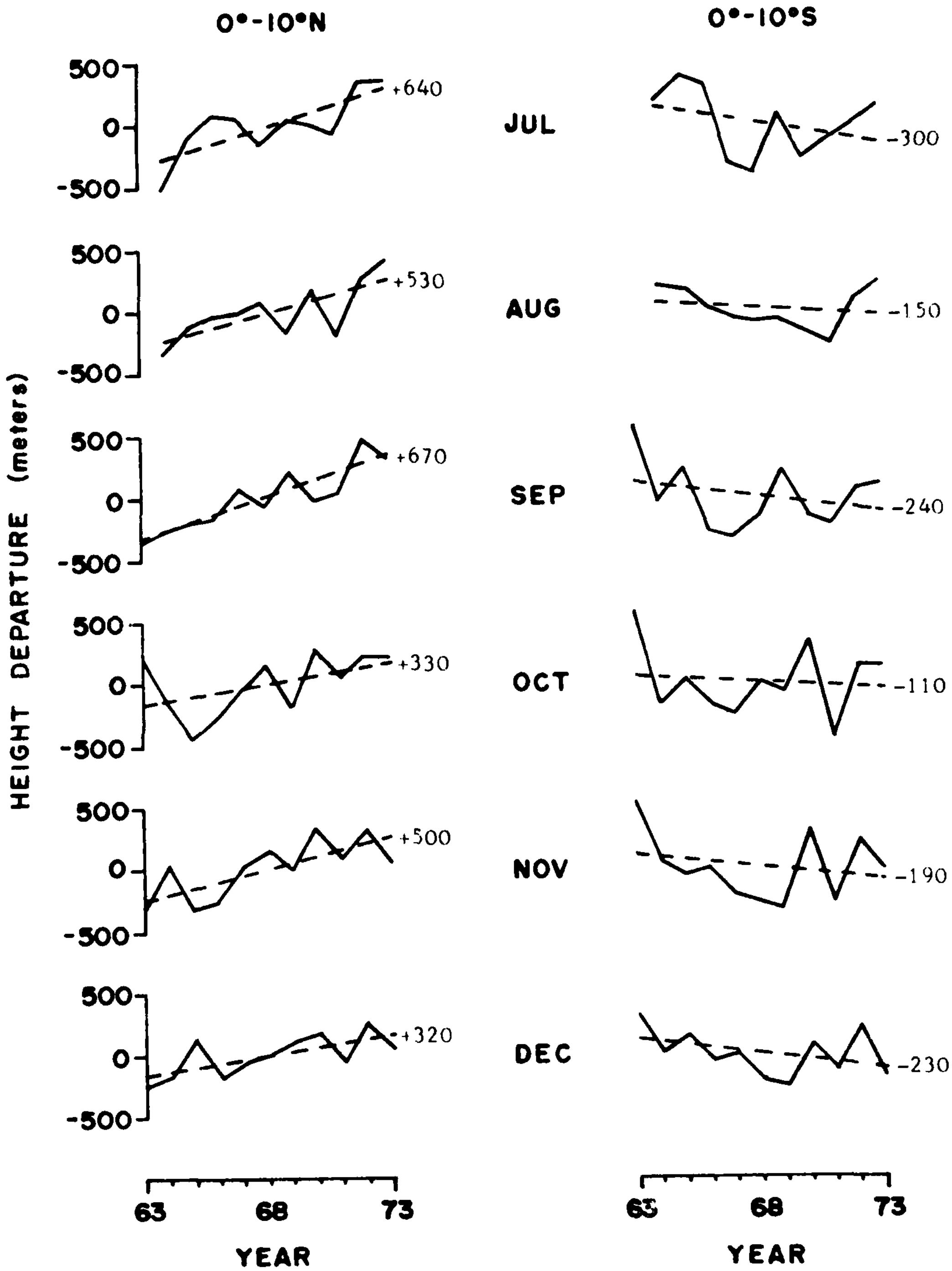

Figure 10b. Same as Figure 10a except for July to December.

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